ITALIAN EXPEDITIONS TO THE KARAKORUM (K^2) AND HINDU KUSH

Prof. A. DESIO Leader

III - GEOLOGY - PETROLOGY

3th Volume

GEOLOGY OF CENTRAL BADAKHSHAN

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GEOLOGY OF CENTRAL BADAKHSHAN (NORTH-EAST AFGHANISTAN)

and

Surrounding Countries

ARDITO DESIO

Editor

E. J. BRILL - LEIDEN

1975

PRINCIPAL COLLABORATORS

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Printed in Italy

PREFACE

The expedition to the Karakorum range which, during the summer of 1954 conquered K^2 (8611 m) — the second highest peak in the world — had, according to Italian tradition, a scientific as well as a mountaineering objective.

Besides the ascent of K^2, the programme of the expedition included research and study on the Geography, Geophysics, Geology Anthropology and Ethnography of the area. Also, a small collection of specimens of local flora and fauna from elevated heights was occasionally made.

The expedition was carried out in three campaigns. A preliminary reconnaissance was made by myself with a guide (R. Cassin), during the summer of 1953. The main stage followed in 1954 and lasted six months; it was carried out by an Italian team of four scientists (Professor Paolo Graziosi, Antonio Marussi, Bruno Zanettin, Captain Francesco Lombardi, topographer, and myself, and a physician G. Pagani), eleven climbers and a photographer; a medical and liaison-officer (Colonel M. Ata Ullah) and an assitant surveyor (Bad Shah Jan of the Survey of Pakistan), both from Pakistan, also joined the staff.

The scientific research was continued in the 1955 campaign which lasted about three months. The team this time consisted of three Italian scientists (Graziosi, Marussi, and myself) and three Pakistani assistants (N. M. Khan of the Geological Survey of Pakistan, M. Azizullah of the Survey of Pakistan, and Javed, a student at the University of Lahore).

The territory examined during the first campaign is to be found between the upper course of the Indus river, from Skardu as far west as the Stak valley, and the principal ridge of the Karakorum to the north. However, some reconnaissance was carried out westwards as far as Hunza and Gilgit and eastwards as far as Bagicha. The territory covered in 1955 lies between the Gilgit area and Chitral.

A new scientific campaign was organized by myself during the summer of 1961 in order to explore geologically the Wahan territory, and to extend westwards the geophysical observations. I was accompanied by Professor Marussi and two assistants (Giorgio Pasquarè and Ercole Martina) and by an Afghan geologist (Ajruddin).

Whereas the geophysical programme was carried out in its entirety, the geological one was reduced to the survey of Central Badakhshan, for the expedition was not allowed to cover Wakhan. Fortunately that area revealed itself to be an important geological knot for interpreting the tectonic connection between the Pamir structures and those of the Karakorum and Hindu Kush ranges.

In order to complete the geological research over an area which had been omitted from the itineraries of previous expeditions and to clear up a number of unsolved problems of its stratigraphical geology, I organized in 1962 a further campaign to the Western Karakorum with two assistants (Ercole Martina and Roberto Galimberti). The territory covered this time is to be found between the Chogo Lungma and the Sosbun glaciers, and the upper valley of the Hunza river.

Two other light expeditions were undertaken by myself in 1970 with an assistant (Giuseppe Orombelli) along the middle Indus valley from Gilgit to Besham Qila following the Karakorum High Way still under construction. Later on, in 1972, I visited alone the Gilgit and Indus valleys between Gilgit and Skardu, and the Stak valley. This journey was devoted to check the Kutiah glacier which in 1953 was subject to an exceptional progress of its front (about ten miles in three months) and in 1954 was photogrammetrically surveyed by the topographers of the expedition.

Some preliminary reports were published in the last ten years to announce the main results obtained from the above mentioned geological and geophysical explorations, but the subject of these reports was and will be largely treated in the volumes of this collection.

The geological results of the 1961 expedition to North-eastern Afghanistan are contained in the present volume which was mostly written by myself toghether with Martina and Pasquarè; but other scientists collaborated in it like Piera Spadea Roda for the Lake Shiwa area, Maria Bianca Cita and Isabella Premoli Silva for the microfossils and microfacies, and Carla Rossi Ronchetti for the megafossils.

One volume of the present series (IV-2nd) published in 1970 is devoted to the illustration of the fossil faunas collected by my 1961 expedition in Badakhshan, Kataghan and Mazar-i-Sherif.

Other collaborations were kindly offered by Piero Guj for the Wakhan and Riccardo Varvelli for the fossiliferous localities of the Wuran Shar pass.

To all my collaborators my heartly thanks.

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I want to express here my thank also to the Afghan Ministers of Foreign Affair, Education and Mining who offered their assistance to the expedition in the bureaucratic arrangements. I want also to remember the kind collaboration offered to our expendition by the officers and particulary the head of the Afghan Geological Survey who supplied us with topographic maps of Badakhshan and joined Mr. Ajruddin as assistant to my expedition.

I am also indebted to the Italian Ambassador in Afghanistan H. E. Folco Trabalza for his kind hospitality in Kabul and his valid assistance in obtaining the permit for our journey. In my heartly thanks I would like include also the officers of the Italian Embassy who helped us in the local arrangements for organising our travel in the country and for sending to Italy the numerous samples collected during our field work.

Ardito Desio

CONTENTS

I. INTRODUCTION

1. GEOGRAPHICAL OUTLINE OF BADAKHSHAN.

The name of this region was well known to MARCO POLO who visited « Balaxiam » (as he called it) in 1273 [1], but then its boundaries did not correspond to those of today. Today Badakhshan is an administrative district ruled by a Governor General (Fig. 1), who also controls Wakhan. This is the corridor about 300 km long extending east-west, dividing north-eastern Pakistan from Pamir (URSS) and communicating eastwards with China.

Present day Badakhshan is bounded for about half of its perimeter by the Amu Darya [2] between Ishkashim and Daung. The river divides it from Tadzhikistan to the north-west, and from Pamir (the eastern part of the Tadzhiks Republic) to the north-east. To the south-east and south the watershed of the Hindu Kush chain marks the boundary of Badakhshan: that is the political boundary, about 60 km long, with Pakistan, and the administrative boundary with the Eastern Province (Nuristan).

At the Anjuman pass the administrative boundary bends directly northwards and without following any geographical feature reaches the Amu Darya near Samti, dividing Badakhshan from the province of Kataghan.

Thus bounded, Badakhshan, without Wakhan, is roughly oval in outline with its major axis oriented parallel to the meridian, about 320 km long and its minor axis 140 km width. The lower course of the Kokcha river, and one of its tributaries, the Warduj river, divide Badakhshan into two parts, that is northern and southern Badakhshan.

The area of Badakhshan is about 50.000 km^2 and Wakhan a further 10.000 km^2 (HUMLUM 1959).

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(1) During the first half of 1300, Badakhshan was travelled by another Italian, the missionary BEATO ODORICO da PORDENONE.

(2) *Darya* means river. The old name of the river was *Oxus*. Upstream from Kokcha confluence the local name of the river is Panj or Pianj.

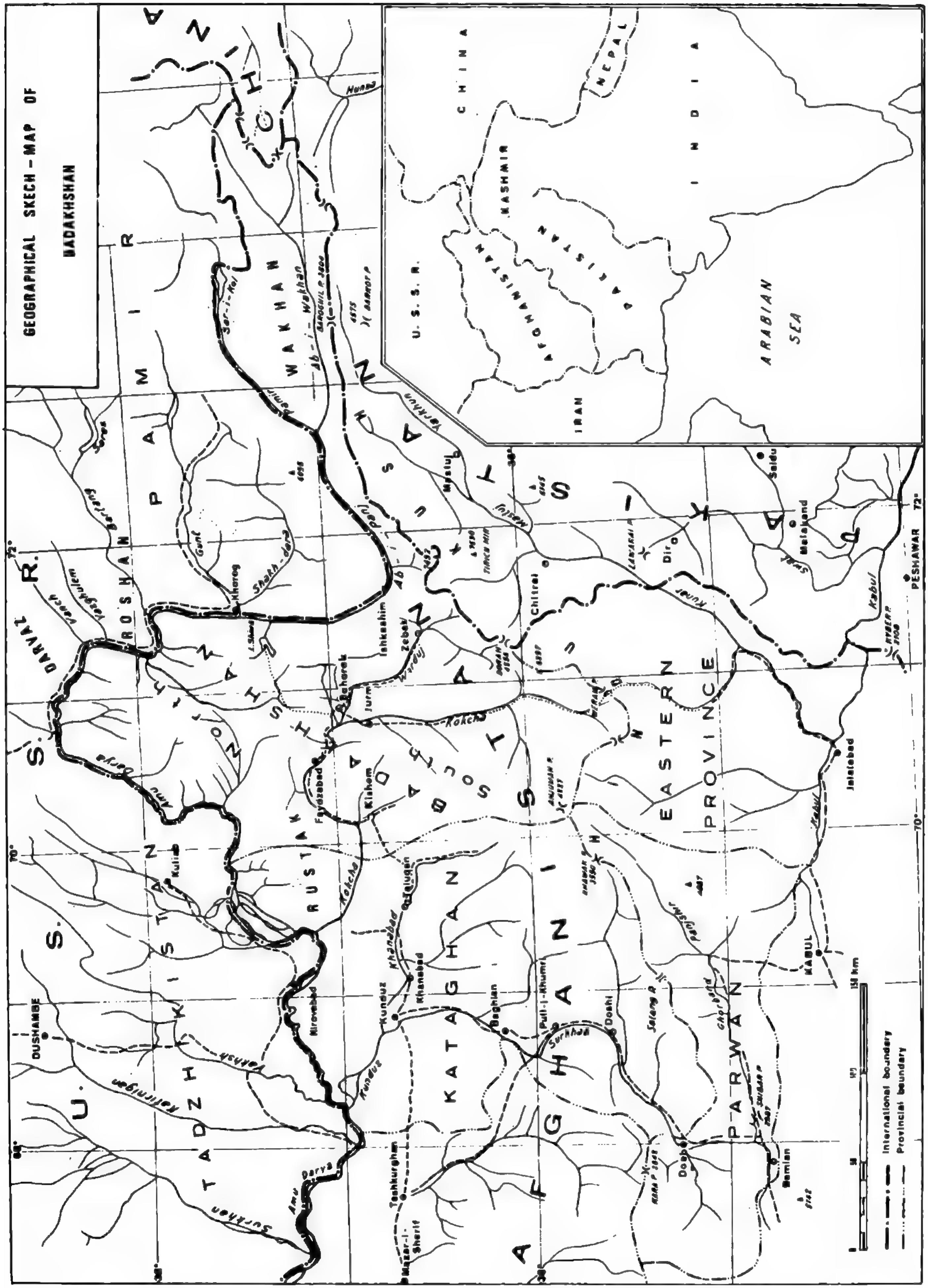

Fig. 1 - Main routes travelled by Desio's Expedition 1961 in Afghanistan (dashed lines by jeeps, dotted by horses).

The geographical coordinates of the province of Badakhshan are 35°28′ and 38°20′ Lat. north, and 69°54′ and 71°40′ Long. east of Greenwich. If the Wakhan corridor is added it extends as far as 74°45′ east.

Almost all of Badakhshan is mountainous with the lower part at an altitude of 800 m above sea level and the highest peaks over 6000 m in the Hindu Kush range, rising to 6843 m in Koh-i-Bandaka, in the south. In the unexplored area included in the great bend of the Amu Darya, there are peaks over 5000 m; the highest attains 5814 m a.s.l.

In this part of the country the landscape exhibits the main features of a residual plateau which is extensively dissected by wide valleys in the upper part and by narrow, deep ravines below the plateau margin.

The information received from the inhabitants indicates that precipitation is very scarse and limited principally to the winter, probably it is greater in the highest regions because we encountered short periods of drizzle rain in August at various altitudes.

The presence of glaciers testifies to the fact that above 3000 m, precipitation is more abundant, chiefly in winter. At Zebak, we were told that in general it does not rain and precipitation is only in the form of snow in winter.

The temperature varies widely from summer to winter, and diurnally, however, we have no precise data available.

The winds too are unknown, but we encountered both mountain and valley breezes which sometimes blew with remarkable strength.

Generally the sky is cloudless but when there is a wind the atmosphere is turbid with dust because the loess deposits are swept into circulation.

The hydrography is very irregular. Apart from the Amu Darya, that flows along the northern boundary of Badakhshan, the principal river is the Kokcha, tributary of the Amu Darya, which with its own tributary, the Warduj, drains the southern two thirds of Badakhshan, except for Wakhan. The western part of Wakhan is drained by the Amu Darya and its left bank tributaries, which flow from the northern slopes of the Hindu Kush. Farther upstream the upper Amu Darya originates from the confluence of the Pamir and Ab-i-Wakhan rivers.

The political boundary with the Pamir province of the USSR is along the Pamir river.

Lakes are scarce in Badakhshan, and are mostly of cirque type. The

only one of considerable size is Lake Shiwa, 13,25 km² in area, near the eastern border of Badakhshan. It is tributary of Amu Darya.

The northern slopes of the Hindu Kush are rich in glaciers which cover the heads of the highest valleys. Small glaciers are also found in Northern Badakhshan, sheltered by the highest peaks in that area.

The main road in Badakhshan leads from Kataghan to Faydzabad, and extends from there east to Zebak and Wakhan. Near Baharak another road branches to Jurm and follows the valley of the upper Kokcha river for a considerable distance. All the other lines of communication are tracks which are often impassable. At present northern Badakhshan has no roads suitable for vehicles.

The resident population of the region is about 400,000 people made up mainly of Tadzhiks of Iranian origin and Uzbeks of Turkish origin. People of the first racial group are the most abundant. The Tadzhiks are the oldest inhabitants of Badakhshan since the Uzbeks invaded the area in the 16th century.

The capital of Badakhshan is Faydzabad, a town on the right bank of the Kokcha river about 1200 m above sea level. It has a population of 25,000 and is the seat of the Governor General. Minor centres are Jurm on the upper Kokcha river, 1560 m above sea level, and Zebak at 2700 m, on the road to Wakhan.

2. THE AREA EXPLORED.

The territory visited by the Italian expedition in 1961 to North-East Afghanistan under the leadership of Professor Ardito Desio, can be divided into two areas, from the point of view of geological research.

The central area, in which the research was concentred and for which a geological map was prepared on a scale of 1:50,000, and

The peripheral area, where rapid traverses and isolated stratigraphic studies were made.

In Badakhshan, however, the area investigated in detail was only the central area, that is between 36°31′ and 37°20′ north Lat. and between 69° 30′ and 70°15′ east Long. of Greenwich while the outer area in which only

occasional isolated research was undertaken lies between 35°50′ and 37°30′ north Lat. and between 67° 00′ and 71° 25′ east Long. of Greenwich.

East of the central area must be added the geological research accompanied by geological mapping on a scale of 1:50,000 in the Shiwa lake basin situated at an average latitude of 37°25′ north and an average longitude of 71°15′ east of Grenwich. Another excursion was made as far as Zebak to the south-east of the central area, to the Hindu Kush, the eastern limit of the area we were permitted to visit.

A much wider area of local research was covered to the west. Occasional observations were made along the route which crosses Kataghan between Kunduz and the western border of Badakhshan with research and partial geological mapping in the area of *Ambar Koh* and around *Ali Abad*. Further to the west stratigraphic research and fossil collections were made along the route from Kunduz to Mazar-i-Sherif, and in particular around Shiboglu Kotal and Tashkurghan.

Towards the south, our expedition had as the occasional goals local stratigraphic studies along the route Kunduz — Pull-i-Khumri — Barfak with the survey of local stratigraphic sequences near the lignite mine of Karkar, around Pull-i-Khumri and Barfak. These latter two localities were visited in 1955 by Desio (1966).

Along the route which leads to Kabul, however, samples of plutonic rocks from the Hindu Kush were collected for to be examined geochemically in order to discover their age (Desio, Ferrara, Tongiorgi 1964).

The area indicated above refers only to that visited for geological studies. A much wider area was explored geophysically and this is referred to in one of the next paragraphs.

3. A BRIEF HISTORY OF THE EXPEDITION.

This expedition like the preceding two much shorter visits in 1954 and 1955 made by the leader of the expedition had as their primary purpose a geological study of the western part of the Hindu Kush mountain chain. Our initial programme was concerned with the study of the northern side of this chain which is bounded on the north by Wakhan, considering the fact

that we were not permitted to cross the tract of country which follows the boundary between North-West Pakistan and Afghanistan.

The choice of the area for geological studies was suggested by the desire to complete the research carried out by Desio on the southern side of the Hindu Kush during his expedition in 1955 (Desio, 1961). Gravimetric and magnetic measurements were made in order to extend towards the west the net of measurements which were taken in the Karakorum area during the expedition to K^2 which was lead by Desio. These are treated in vol. 1 ser. II of the present collection.

In 1955 Desio made a purely reconnaissance visit to northern Afghanistan reaching as far as Kunduz, in Kataghan, with the scope of gaining knowledge of the local logistical problems and the practical necessities for organising a journey in the north-eastern part of the country. For various reasons this expedition was postponed from year to year.

In the meanwhile the data collected during the expedition in 1955 was coordinated and united in a report which presented certain new features distinguished in the area visited, without the pretence of presenting substantial progress in the general knowledge of Afghanistan.

Finally in the winter of 1960-1961, through the Italian Ambassador in Kabul, a request was made to visit the north-east part of Afghanistan. As a result of a certain delay in the preparations for the journey and in obtaining the necessary permits we were obliged to abandon the idea of reaching Kabul by sea through Karachi and then Peshawar. We used therefore the airlines which link Milan to Teheran and after a brief stay in Iran we reached Kabul by using the local airline.

On the 20th July 1961 the members of the expedition disembarked with their equipment at Kabul airport. Apart from the expedition leader Professor Ardito Desio, these included Professor Antonio Marussi of Trieste University, the expedition geophysicist, Dr. Giorgio Pasquarè and Dr. Ercole Martina geologists, both Professor Desio's assistants. At Kabul we were joined by Mr. Ajruddin, a geologist of the Afghan Geological Survey.

In Kabul the Italian Embassy, headed by the Ambassador Folco Trabalza, put itself at our disposal to facilitate our local organisation and enable us to continue our journey into the interior. We needed to complete our stocks of food, to obtain three jeeps for about two months and above all to obtain valid permits to enter Wakhan Thanks to the valuable assistance

of the Embassy staff, the organisation of our expedition was rapidly completed, however it took a long time to obtain permits to enter Wakhan. In spite of Ambassador's personal efforts and the helpful assistence of the Afghan Foreign Affairs Ministry, the Ministry of Education and the Ministry of Mining, we had to wait three weeks in Kabul before been able to set out on our journey.

The permit to enter Wakhan was not granted, thus we had to limit our studies to a part of Badakhshan which we were allowed to visit extending to about ten miles from the border with Tadzhikistan. If at the time the renunciation of our visit to Wakhan was a disappointment we found out later that the political constraints had made us devote our researches to an area of much greater geological interest. As we shall see in fact during the course of the present study, Badakhshan represents a key area which clarifies many geotectonic problems, which Wakhan certainly could not have offered.

However on the 2nd August we left the capital with three locally hired landrovers and headed northwards. We followed the route from Kabul through the Shibar Pass, Doab, Pull-i-Khumri and Kunduz, about 514 km and the night of the 4th August we pitched our camp at Faydzabad (247 km from Kunduz), the main town of Badakhshan, 1200 m above sea level.

After making essential local contacts, on the 12th August the geological group started immediately a reconnaissance of the neighbourhood, while MARUSSI set out in a landrover for the Jurm valley, the Daran pass and Nuristan in order to carry out the programme of gravimetric and magnetic measurements along transverse lines across the axial trends of the mountains. PASQUARÈ's studies were directed in particular to the mapping of the areas composed predominantly of crystalline rocks, MARTINA to the areas of sedimentary rocks, while DESIO helped either one or the other, during the geological mapping, in order to direct the identification of the various formations, or preceded his collaborators towards the same end. This method of working was imposed also by the fact that we only had one series of topographic maps on a scale of 1:50,000 at our disposal, which were generously supplied by the Afghan Geological Survey. These maps however did not cover all of Central Badakhshan, thus our geological mapping was concentrated in the area of the available maps, as one can deduce from the particular shape of our geological map at 150,000 scale included in this volume.

Another limitation on our work was determined by the scarcity of roads suitable for motor vehicles, thus we tried, wherever possible, to remain close to the only motorable road existing at that time in Badakhshan, that is the one linking Taluqan with Faydzabad and the latter with Zebak and with the upper valley of Jurm. In fact leaving this track the only lines of communication were represented by caravan routes, and paths negotiable by horses and mules. On foot and with these means of transport the area north, north-east and east of Faydzabad as far as Lake Shiwa and that situated of the road from Kishem to Farkhar was mapped.

On the sketch-map on fig. 1 are indicated the traverses made by the geologists during the course of their work which was finished at the end of September.

Unfortunately an unpredicted political incident interrupted our field studies. A diplomatic incident between Afghanistan and Pakistan which happened during the second half of September caused restrictive measures to be taken by the Afghan government especially in connection with petrol supplies. The measures caught us unprepared and as a result we were forced to change our programme immediately and try to return to the capital somehow to avoid an eventual worsening of the political situation which could have forced us to remain in the interior, separated as we were at that time, from each other. The order to return to Kabul, which the expedition leader was forced to give, enabled all the members to return to the capital in a relively short time, where it was discovered, that among other things the frontier between Afghanistan and Pakistan was closed.

Our programme to return with all the material collected via Peshawar-Karachi was yet again abandoned and we were forced to organise the transport of men and material by air, which was economically more onerous even if quicker.

Thus, having exhausted the laborious arrangements which preceded the departure, on the 5th October we left Kabul airport and after a brief stay in Teheran to transfer the collections from one airline to another, the expedition returned home on the 7th October.

4. GEOPHYSICAL RESEARCH.

This is not the place to present the detailed results of geophysical research undertaken by the expedition, but they should be discussed here briefly because of the great interest this research has in particular for an interpretation of the regional tectonics.

It was for this reason among others, that Professor A. MARUSSI was asked to participate not only in the 1961 expedition in Badakhshan, but also in two previous DESIO's expeditions (1954 and 1955) to the east, in the Karakorum (MARUSSI, 1963, 1964).

GRAVITY — Before the DESIO expedition in 1961 no gravimetric determinations had been made in Afghanistan. For this reason preliminary results were based on a link of a known gravimetric station and a chosen, easily accessible, locality (near Kabul). This gravimetric station was adopted as a starting point for relating all the determinations made during the expedition's course. The instrument used was an accurately adjusted Worden gravimeter.

The selected gravity station, situated at Mehrabad airport, is named the « Iranian National Gravity Station », to which the value of g = 979.447,400 mgal has been attributed. This value is derived from numerous links with European and American base stations established in the past by numerous observers. The choice of Teheran was the result not only of the good gravity values obtainable there, but also of the fact that the air link between Teheran and Kabul is served by a rapid air service. The gravimetric link between the stations at Teheran and Kabul was assured by return flights with intermediate stops at Zahedan and Kandahar, where it was also possible to determine the relative gravity.

The base station in Afghanistan was established in Kabul, to be precise on the verandah on the eastern side of the Afghan Geological Survey in the Dar Ul Aman suburb. The value determined was g = 979.123,820 mgal.

The subsequent survey was made along two closed traverses and along certain subsidiary lines with a total extent of about 1750 km. The first closed traverse was undertaken during the first phase of the campaign. Leaving Kabul it crossed the Hindu Kush range from south to north along the motor road from the capital to Doab, Pull-i-Khumri, Kunduz and Faydzabad. From Faydzabad it followed the mule trail and the rough paths which again

cross the Hindu Kush range passing through Mazar Shah Khusrau, the Weran pass, Wama, ending at Kandi Alakadari where a motorable road returns to Kabul passing through Chiga Serai, Jalalabad and Sarobi.

The second closed traverse again started in Kabul, passing through Bamian, Band-i-Amir and Panjao and returning to Kabul, following throughout the motorable roads.

The supplementary trasverses started in the first case from Doab and extended to Hajar; another started from Faydzabad and ran as far as Zar Khan (Zebak); yet another originated at Kabul and ran as far as the Zinia Alakadari in Panjshir; and the last line was from Kabul to Ghazni.

All together 63 observation stations were established and were well distributed along the routes described above, forming therefore a rather dense net in the north-eastern part of the Afghanistan Hindu Kush.

At all the 63 gravimetric stations the altitude was determined using Thommen geodetic altimeters, thermobarometers and other accessory instruments. At the same stations measurements of the Earth's magnetism were also made (see below).

The result of the gravimetric measurements are presented in a study by Marussi (1963) together with a discussion and coordination of the results with those from previous expeditions. A synthesis on two maps of the Bouguer anomalies and the Airy isostatic anomalies for a vast area which naturally includes eastern Afghanistan is also presented.

Magnetism. — In the course of the 1961 expedition, the magnetic observations made in the Karakorum range at the time of the 1954 and 1955 Desio's expeditions, have been extended to the western Hindu Kush area.

As we have amply illustrated in a previous volume (Marussi, 1964), the aim of the magnetic survey was to extend the existing surveys to the unexplored areas of the Karakorum-Hindu Kush region the repetition of as many as possible of those stations already observed in the past, in order to determine the secular variations of the magnetic field, and the production of a general map including all observations so far made in the region, so as to contribute to the geophysical interpretation of the geology of the country. In all expeditions of 1954, 1955 and 1961, the vertical component Z and the horizontal components H have been observed. Observations of declination have also been made in 1961 in the Chitral and Gilgit area.

All magnetic observations carried out in 1954 and 1955 are referred to

the Repeat Station Rawalpindi 1955.0, and have been reduced to this epoch by using the data supplied by the Magnetic Observatory at Quetta (Pakistan); the computed anomalies are referred to the « undisturbed field » as given by the Survey of India [1]. 43 stations have been observed in 1954 in the Karakorum, and 26 in 1954 in the Chitral-Gilgit area. The results of the observations made, are synthetized in two maps published (MARUSSI, 1964) showing the vertical force and the horizontal force anomalies, in which an attempt has been made to include all data available from previous observations.

The magnetic observations of the 1961 expedition are referred to the Amirabad Station of the Magnetic Observatory of the University of Teheran (Iran); we are glad to express on this occasion our gratitude to its director, Professor H. K. AFSHAR, for the kind assistance he has always estended to us.

The reduction of the observations to epoch 1955.0 has been carried out using the data supplied by both the Amirabad and the Quetta Observatories. 23 stations have been observed in 1961, along the routes shown in fig. 1. The fundamental station in Afghanistan was established in a field in front of the building of the Geological Survey near Kabul.

5. GEOLOGICAL KNOWLEDGE PRIOR TO DESIO'S 1961 EXPEDITION [2].

If the words « geological knowledge » are given a wider than usual meaning, to MARCO POLO can be attributed the first information on the countries mineral resources.

« On the province of Balazian, and the precious stones there found, called Balasci », is the introduction to the chapter of *Il Milione* in which he refers to the territory studied by us.

Apart from the balas-rubies, which were mined on the right bank of the Amu Darya, outside the limits of present day Badakhshan, MARCO POLO

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(1) GULATEE, B. L. - *Charts of Declination, Horizontal Force and Vertical Force for Epoch 1953. O and Magnetic Anomalies (India, Pakistan and Burma).* « Survery of India - Technical Paper », n. 7, 1954.

(2) Of the publications which have appeared successively, notes will be given during the course of the work, as the occasion arises.

spoke of lapis-lazuli and other minerals stating that « there are also mountains where the veins of stones from which the best blue in the world is found occur, together with other veins which produce silver, copper and lead ».

As well as this information which dates back to the 13th century and other vague references during the following centuries, only during the first half of the last century do we find some mining data, which gives details of the lapis-lazuli mine in the upper Kokcha valley (J. WOOD, 1841), a mine well known since ancient times. The first real geological information on Badakhshan was given in a short paper by J. BARTHOUX (1929) who visited the region during that year. He states [1]: « Le Badakhshan est gneissique au centre et à l'Est, constituant ainsi le prolongement de l'Hindou-Kouch.

Les gneiss s'etendent à l'Ouest jusqu'à Kala-Yaoun et au Nord, ils ne dépassent pas Kala-Oumar. Leur bordure Nord et Ouest est formée de schistes verdâtres azoïques, mais dans le Daoung se retrouve le dévonien du col d'Hadjikak. De là et sur la bordure occidentale du Roustak s'etendent les grés redressés de Sioualik (miocène), grès grigeâtre, *sel et poivre*, avec intercalations fréquentes de conglomérats. Cés grès sont très relevés, jusqu'à 70°, de direction N 75° E et pendent au SSE. Dans le Tahâi-âb, ils deviennent horizontaux. Aux environs de Roustâk, ils couronnent stratigraphiquement des formations anciennes dont je n'ai pu déterminer l'âge.

Dans le gneiss apparaissent des grands bancs de cipolins très mineralisés et qui suivent les plans de gneissification. On y trouve géneralement des spinelles et de la phlogopite en abondance ».

BARTHOUX also recorded the lapis-lazuli deposit in the upper Kokcha valley and provides mineralogical details in other publications during 1933.

The most important geological report on Badakhshan prior to the DESIO's Expedition in 1961 was published in 1935. This was the paper by K.

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(1) « Badakhshan is gneissic from the centre eastwards, thus forming an extension of the Hindu Kush.

The gneiss extends as far west as Kala-Yaoun, and to the north it does not extend beyond Kala-Oumar. The northern and western limits are formed of unfossiliferous greenish schist, but in Daoung the Devonian is found on the Hadjikak col. From there and on the western limit of Roustak steeply dipping Siwalik sandstones (Miocene), greysh, speckled sandstones, with frequent conglomerate intercalations extend. These sandstones are steeply inclined up to 70° striking N 75° E and dipping to the SSE. In Tahâi-âb they become horizontal. Around Roustak they are surrounded stratigraphically by older formations the ages of which are unknown.

In the gneiss thick heavily mineralised beds of cipolins are present which follow the layers of gneissification. Generally spinel and phlogopite are found in abundance ».

Brückl on Badakhshan and Kataghan. Brückl discussed Badakhshan in about twelve pages, dividing the content into areas following various routes:

a) The Kokcha valley from the Anjuman pass as far as Faydzabad,

b) The region between the Kokcha river and the Amu Darya (Warduj-Zebak - Ishkashim - Wakhan - Zardew),

c) Faydzabad and the boundary with Kataghan.

The area partially surveyed by Brückl lies south of the parallel through Faydzabad and extends from the Amu Darya, between Ishkashim and Andaj, as far as the western boundary of Badakhshan. The region beyond the area mentioned above is blank.

The stratigraphical sequence recorded by Brückl in Badakhshan can be summarised as follows: From the top:

a) Tertiary conglomerates,

b) Red Grit series,

c) Ghordand and Helmand series,

d) Calcareous shales series,

e) Serpentine,

f) Wakhan slate.

Among the igneous rocks Brückl mentions granites and diorites near Baharak (Bohrak) and in the upper Anjuman valley, where they form the « Central massif of the Hindu Kush ». According to the same author the major part of the territory between the Kokcha river to the west, and the Amu Darya to the east, is composed of the calcareous schist series. This is chiefly composed of quartz-hornblende schist, black staurolite slate, gneis and marble, all crossed by numerous granite intrusions. Serpentines are located getween Zebak and Ishkashim, the Ghorband and Helmand series in the Anjuman valley, where the Red Grit series (red conglomerates) is present also. This series is indicated again at the contact with the serpentine outcrop mentioned above. Wakhan slate is present in the Kokcha valley downstream from the confluence of the upper tributaries of the Kokcha river, the Ab-i-Anjuman and the Ab-i-Munjan.

Brückl mentions a diabase intrusion which has folded and strongly compressed the crystalline slates. On a subsequent page he speaks of in-

tense folding in the calcareous schist series. An impressive line of tectonic disturbance is also mentioned between the Anjuman pass and the confluence on the Kokcha river.

Subsequently he mentions that along the road between Faydzabad and Taluqan, west of Chenar-i-Gunjeshkan, the boundary of the region composed of sedimentary deposits occurs. These rocks are limestones, conglomerates, sandstones, marls and siltstones. Brückl also records salty water.

He also describes the saline series of Namakan, that is in Kataghan. He found no fossils in the territory surveyed by us, so that all the chronostratigraphic attributions were deduced by comparing his stratigraphic units with the fossiliferous series of Hayden (1911) and are described by Hayden in a table at the end of Brückl's paper (Hayden 1935).

Brückl states that he did not find marks of Quaternary glaciers during his travels, not even in the upper Kokcha drainage basin, where he pointed out the presence of a lake formed by a landslide, a few kilometres downstream from the confluence of the Ab-i-Anjuman and the Ab-i-Munjan.

The above mentioned works contain the only really interesting geological data on Badakhshan before our survey of 1961.

We have to add to this knowledge a very short report, but accompanied by numerous sketch-maps, of H. Sawata, who participated as geologist to the Japanese mountaineering expedition in 1960 to Mount Noshaq (7490 m), in Hindu Kush (Sawata, 1962). We did not know about Sawata's report until later; it will be mentioned when the subject is dealt with in the following sections. The itineries followed by Sawata in our region, and mentioned in his report are: a) Faydzabad-Baharak-Shiwa lake; b) Baharak—Zebak—Ishkashim. Then he explored the Wakhan as far as Qaz Deh and the tributary valley coming from Mount Noshaq. He did not collect any fossils in this region, so that the age of the formations remained unknown. To the Cenozoic was (possibly) attributed the « Zebak conglomerate » and the « Dasht-i-Amani alternation » of the area between Faydzabad and Kishem. This is « a formation of monotonous alternation of sandstone and mud-stone containing drift wood and mammalian bones... This formation is supposed to be several km or more thick, and its age is supposed possibly of Pliocene—Pleistocene, though no fossil of a decided age has yet been found. A synclinal axis plunging to the south is known in the formation at the mouth of the Teshkan river ».

This formation corresponds to our Kokcha Formation and, for the most part, to the Ghelawuk Member of it. Much more information concerning the Pleistocene deposits are contained in SAWATA's sketch-maps. We will report them when we deal with this subject.

We know of no other geological reports on Badakhshan, but many Russian authors who have studied Pamir mention Badakhshan even if they do not refer to surveys that they have made in the region.

We do not know the Russian geological literature well enough to be able to exclude the possibility that a report of this kind could exist. The only report of which we were aware in 1961, was a paper by D. NALIVKIN (1932) in which Badakhshan was referred to in the title.

Finally it should be remembered that the Afghan Geological Survey gave us an unpublished schematic geological map of a part of Badakhshan on a scale of 1:250.000, prepared by a French team during a survey for radioactive minerals. The map records: « Calcaires metamorphiques, Zone de Schistes, Zone de Gneiss, Amphibolites, Migmatites, Granulite orientée ».

These works are the only sources of geological information we consulted before carrying out our survey. The publications which appeared subsequently will be mentioned in the text as the occasion arises.

However we must state here that in the long period during the preparation of this volume and its delivery to the press we have considered it advisable to bring to notice certain results of particular importance for the knowledge of Badakhshan, publishing works which we limit ourselves to list in the bibligraphy, also because in subsequent works by various authors they have been often forgotten. It must also be mentioned that in the meantime a volume (IV, vol. 2°, 1970) dealing with the palaeontology has been published in this series, in which both micro and macro-fossils are illustrated. These were collected during the expedition and by occasional collaborators who followed us and visited some localities of particular palaeontological interest.

It is considered useful to include below only the titles of the palaeontological studies contained in the above mentioned volume. About the studies of foreign authors published during the preparation of the present volume, mention will be made within the sections, when the subject of those studies will be treated. Nevertheless some of them were received (or appeared) too late for giving an account in this book.

SCHOUPPÉ A. (VON). - *Lower Carboniferous Corals from Badakhshan (North-East Afghanistan.* Pages 3-22, 3 plates.

BARNARD P. D. W. - *Upper Triassic Plants from the Kalawch River, Badakhshan (North-East Afghanistan).* Pages 25-40, 3 figs., 2 plates.

ROSSI RONCHETTI C. - *New Contribution to the Knowledge of the Jurassic Fauna of Karkar (North-East Afghanistan).* Pages 43-74, 6 figs., 2 plates.

BERIZZI QUARTO DI PALO A. - *Upper Cretaceous Molluscs and Brachiopods from Badakhshan (North-East Afghanistan).* Pages 77-118, 1 fig., 5 plates.

PREMOLI SILVA I. - *Cretaceous-Eocene microfaunas from Western Badakhshan and Kataghan (North-East Afghanistan).* Pages 119-160, 9 plates.

BERIZZI QUARTO DI PALO A. - *Paleogene Pelecypods from Kataghan and Badakhshan (North-East Afghanistan).* Pages 161-240, 1 fig., 16 plates.

6. SUBDIVISION OF THE TERRITORY INTO GEOLOGICAL ZONES.

It can be easily seen from an examination of the geological map included in this volume that the territory studied by DESIO's expedition of 1961 can be divided into two parts from the point of view of the stratigraphy. The eastern part is composed mainly of plutonic and metamorphic rocks; the western part mainly of sedimentary rocks of normal facies. These characteristics are maintained beyond the central area both to the east and west.

The boundary between the two parts is not clearly defined. As will be best seen in the tectonic section, the main town of Badakhshan, Faydzabad, lies on the western side of a structural high aligned approximately north-south which separates two areas not only different in composition but also with a different geological structure. In the first, as stated above, plutonic and metamorphic rocks are predominant and the tectonic structure is characterised by a series of blocks, separated by faults aligned in the direction of the meridians, compressed together and also overthrust on one another; in the second area however sedimentary rocks are predominant which are affected by weak folds and modest faults.

In spite of outcrops of plutonic and metamorphic rocks to the west of Faydzabad, as a geological boundary between the two parts the western limit of the Faydzabad structural high can be accepted when account is ta-

ken of the general north-south strike of the strata which pass about ten kilometres west of the main town.

However, to be brief, we shall refer to them simply with the names area east of Faydzabad for the eastern part of Central Badakhshan, which includes the structural high and the territory farther to the east, and as the area west of Faydzabad that situated to the west of the structural high, as far as Kataghan.

7. SUMMARY OF THE GEOLOGY OF CENTRAL BADAKHSHAN.

In order to introduce the reader on the geology of Central Badakhshan we think it will be useful to give him a general frame of the geological composition and structure of the territory described in this report.

STRATIGRAPHY. - The formations of Badakhshan were divided into three groups in accordance with their petrographical features. The groups are: sedimentary formations, metamorphic formations and igneous rocks.

As detailed studies were previously lacking for this territory the names of about all the formations are new.

The sedimentary formations of our territory, owing to tectonic and facies reasons, are distinguished in two parts in relation with the geographical position, that is the ones lying east of Faydzabad and the ones lying west of it.

A) SEDIMENTARY FORMATIONS OF THE AREA EAST OF FAYDZABAD.

From the bottom to the top they are:

a) *Kalawach Limestone* (Kal), sometime arenaceous and fossiliferous belonging to the Upper Devonian (Lower member) and Lower Carboniferous (upper member);

b) *Furmoragh shales (and black slates)* (Fbs) with fossil plants of the Upper Triassic;

c) *Wuran Shahr Limestone* (Wsl), microcrystalline, with fossils of the Upper Jurassic;

d) *Pa-in-Shahr Limestone* (Pf), with evaporite facies, possibly belonging to the Upper Jurassic.

A') SEDIMENTARI FORMATIONS OF THE AREA WEST OF FAYDZABAD.

From the bottom upwards:

a) *Farkhar slate* (Fs): dark arenaceous slate with basal layers of sandstone, quartzite and conglomerate (age unknown);

a') *Shingan Conglomerate* (Sf): grey and greenish conglomerate with interbedded greenish fine sandstone with some remains of fossil plants and pelecypods: Lower (?) and Middle Jurassic.

b) *Qara Bulaq Sandstone* (Qf): reddish and greenish fine quartz-sandstone with intercalations of green and red arenaceous siltstone. Some beds of reddish conglomerate. Middle Jurassic — Lower Cretaceous.

c) *Gazestan Formation* (Gf): alternation of red, green and grey conglomerate, red shale and sandstone, gypsum and grey fossiliferous limestone. Large lenses of rock-salt. Albian.

c[1]) *Mashad Limestone* (Ml): grey well-bedded limestone grading laterally into sandstone. Lower Cretaceous — Cenomanian (?).

c[2]) *Mohammed Aba Sandstone* (Ms): dark-green and reddish compact quartz feldspathic sandstone. Lower Cretaceous — Cenomanian (?).

d) *Baba Darwes Formation* (BDf): grey and brown limestone, often weathering yellowish, and red marl. Very fossiliferous. From Albian — Cenomanian to Palaeocene.

e) *Bluti Formation* (Bf): grey marl and limestone very fossiliferous. Middle — Upper Eocene.

f) *Kokcha Formation* (Kf): grey sandstone and conglomerate, prevailing (Tah Jari member); grey marl and sandstone in the upper part (Ghelawuk member); boulder conglomerate cemented by arkosic sand, locally at the base (Ganda Qol member). Neogene.

B. Metamorphic Formations.

a) *Faydzabad Gneiss* (Fg): kinzigite, kinzigite-gneiss, biotite-garnet-gneiss with marble and amphibolite intercalations. Pre-Devonian problably pre-Cambrian.

b[1]) *East Rabat Gneiss* (Rg): fine-grained biotite gneiss, garnetiferous at the base (east of Faydzabad); with interbedded marble, thickly injected at the contact with the Abu Abdal Granite. Pre-Devonian, probably Lower Palaeozoic.

b[2]) *West Rabat Gneiss*: fine-grained biotitic paragneiss garnet and sillimanite bearing, inferiorly alternating with marble and calc-phyre. Probably Lower Palaeozoic.

c) *Qara Mughul Gneiss* (Qg): medium-grained biotite gneiss (west of Faydzabad); with interbedded marble. Pre-Devonian, probably Lower Palaeozoic.

d) *Halqa Jar Amphibolite* (Hg): mostly massive, fine- or medium-grained amphibolite. Pre-Devonian—Jurassic.

e) *Kurkhu Gneiss* (Kg): migmatitic gneiss, banded gneiss, augen-gneiss.

f) *Tarang Gneiss* (Tg): migmatitic gneiss, mostly nebulitic, of various composition (from dioritic to pegmatitic), grading into Baharak Granodiorite.

g) *Sialic gneiss granite* ($g\gamma$): locally porphyroblastic (augengneis), or garnetiferous.

h) Black shales and slates (bs): dark arenaceous black shales and slates with quartzite layers.

C. Igneous Rocks.

a) *Jalmish Tonalite* ($I\gamma$): tonalite and quartz dioritic peripheral leuco-gabbro, granodioritic and leucogranitic facies. Permo—Triassic.

b) *Naghz Darra Tonalite* ($N\gamma$): tonalite, quartz diorite, leucogranite, often cataclastic. Jurassic—Cretaceous.

c) *Muzung Gabbro* ($M\delta$): gabbro and olivine gabbro with small bodies of anfibolic gabbro and peripheral gabbro-dioritic facies. Jurassic—Cretaceous.

d) *Kakan Quartz diorite* ($K\gamma$): rather monotonous horneblende-quartz diorite. Tertiary.

e) *Petwan Blastomylonite* (Pb): blastomylonitic and cataclastic quartz diorite. Blastomylonitic facies of the Kakan Quartz diorite.

f) *Abu Abdal Granodiorite* ($A\gamma$): leucocratic granodiorite with leucogranitic apophysis. Tertiary.

g) *Baharak Granodiorite* ($B\gamma$): porphyroblastic microcline-biotite granodiorite and gneissose biotite quartz diorite. Age unknown.

D. Pleistocene and Modern Continental Deposits.

a) *Taluqan gravel* (Tgr): sometimes slightly cemented, sometimes with graded bedding.

b) Ancient (aa) and recent (ra) alluvial deposits.

c) Ancient moraines and old fluvio-lacustrine deposits (am). a) Recent moraines (rm).

e) Loess (lo).

f) Plateau alluvial deposits with loess (pa).

g) Lacustrine deposits (la).

h) Landslide (l) and talus (t).

E. Tectonics.

Under the point of view of the tectonics the Central Badakhshan may be divided into three tectonic zones, which have different structural characteristics.

1. An *Eastern zones,* from Baharak (Shiwa fault) eastwards as far as the Zebak-Munjan fault, where the metamorphic formations (Kurkhu Gneiss, East Rabat Gneiss) are folded in anticlines and synclines and are sometimes faulted. In this zone the bedding strike and the fold-axes are generally oriented NNW-SSE. A large pluton is present north-east of Baharak (Baharak Granodiorite) on the right bank of the Zardew river. The zone to the south-east is that of Hindu Kush.

2. A *Central zone,* between Baharak and Rabat (Jurm fault), is wholly composed of sedimentary rocks, like Devonian-Jurassic limestone, and the lightly metamorphosed black slates. The beds are folded and repeatedly faulted and the width of the tectonic zone becomes narrower and narrower from the north to the south. We may consider the zone as a synclinorium.

3. A *Western zone,* between Rabat and Kakan (Petwan faults), characterized by the important anticline of Faydzabad, whose core is formed by the most ancient rocks known in the zone, the Faydzabad Gneiss. As in the eastern zone, the outcrops (Faydzabad Gneiss, West Rabat Gneiss, Qara Mughul Gneiss, Halqa Jar Amphibolite) and the fold-axes are prevailingly oriented NNE-SSW. North of Faydzabad, the fold-axes turn northwards, because of a mass of igneous rock constituting an obstacle to orogenic movements.

To the west follows the Kataghan zone, from Petwan towards Taluqan, where the formations (Farkhar black slates and Cretaceous and Tertiary formations) have in general a NE-SW strike. In this zone, a large igneous body occurs between Farkhar, Ganda Qol, and the Maskad valley; igneous rocks also form a band, with approximate NNE-SSW strike, between the Halqa Jar Amphibolite on the east, and the black slates on the west, from Kakan as far as the Mashad valley (near Kishem). This lenticular intrusion, with its blastomylonitic facies, is an important element in the geological structure and history of the region. The granodiorite was probably intruded along a stratigraphical and tectonic discontinuity in the western side of the Faydzabad anticline, between the Halqa Jar Amphibolite and the plastic black slates, which acted as impermeable blanket to the intrusions. North-west of Faydzabad, where the Halqa Jar Amphibolite is best developed, the igneous rocks deviate north-north-westwards. After the Kakan Quartz diorite intrusion, a sinking movement occurred in the western zone,

and Tertiary sediments were deposited in the trough (Upper Amu Darya Depression of TUAYEV, 1961). These sediments were subsequently dislocated. At the same time, further folding of the Faydzabad anticline continued, which assumed the shape of a fan-fold. This tectonic movement occurred repeatedly, as is shown by angular unconformities between several deposits, some of them of Cretaceous, some of Tertiary age. At the same time, part of the granodiorite, under high pressure, was subject to mylonitization followed by recrystallization which turned the rocks into blastomylonites (Petwan blastomylonite).

Considered in a larger tectonic frame, the region described above is located in a tectonically very complex area. It lies in the south-westward point of convergence of the tectonic structures forming the Pamir and is also near the contact of these structures with those forming the Hindu Kush range to the south.

II. STRATIGRAPHY

1. INTRODUCTION.

We shall start with the sedimentary formation from which it is possible to obtain elements of judgment on the age of the metamorphic and plutonic formations, because at least in part they have provided determinable fossils. We shall then pass to the metamorphic formations and subsequently to the plutonic ones. However before describing the various formations a preliminary clarification is necessary.

The concept of the *formation*, according to the international norm ([1]) demands a precision it is not always possible to establish. Not all of our formations represent therefore « formal » stratigraphic units because they lack some of the data required by the norm. In spite of this in these cases, which in reality are in the minority, we have considered it useful to adopt a formational nomenclature which enables one to determine rapidly, and, up to a certain point, independently of age the various groupings of the beds. We can distinguish the « informal » formations by using the lower case for the second term.

We have maintained the formational concept also in the subdivision of the metamorphic rocks for which norms have been used analogous to those used for the sedimentary rocks.

Bearing in mind the small amount of geological research in Badakhshan before our 1961 expedition it was necessary to introduce numerous new formations with local names. It is possible that some of these correspond more or less to formations already noted in neighbouring territories, specially in Pamir and Tadzhikistan — and in certain cases we have identified them — but when the correlations are not secure we have preferred to adopt the local name which could be synonymous with the other, but avoids false cor-

(1) Report on the 21st Session of the International Geological Congress, Copenhagen 1961.

relations which are much worse than two names. In certain cases in which too many elements are lacking to create a new lithostratigraphic unit we have used a generic nomenclature designating the groups of beds with generic lithological descriptions in order to individualise them in some way.

We believe that this method is more practical and rational than that used widely in Afghanistan of placing the stratigraphic subdivisions in « series » more or less chronologically defined. The series are in fact local successions of beds, mapped occasionally, without any stratigraphic limit defined above or below, which do not represent commonly neither lithostratigraphic units, chronostratigraphic nor biostratigraphic, and for this reason it is very difficult to represent them on geological maps.

We shall start our review of the formations with those of sedimentary origin because they are more significant, more easily datable and better delimitable. We shall follow these with the metamorphic formations and finally pass to the description of the igneous rocks which can be also classified using formational concepts.

The formations are reviewed in the chronological order, starting with the oldest. But the order of the succession cannot be rigorously respected because of the existence of numerous coeval formations which pass laterally into one another. In this case the succession will be more or less casual or follow a geographical order.

A. SEDIMENTARY FORMATIONS

α. AREA EAST OF FAYDZABAD.

1. GENERAL OUTLINE.

A thick calcareous-dolomitic sequence (partly metarmophosed) is present east of Faydzabad between the Rabat Gneiss to the west and the black shales to the east and outcrops on the mountains rising to the north-east of the Kokcha river, in the region bounded by the Jurm valley to the south and the Koh-i-Sur Khan. Two thick calcareous bands dip towards the Kokcha river between Rabat and Baharak: one upstream of Wular, the other near Furmoragh. Further to the north, in the Khambew region, these bands

thicken rapidly and join together to form most of the mountain ranges bordering to the west the valley of the Shiwa river north of Baharak, towards northern Badakhshan.

Several different lithological units varying in age (according to the fossils) from Upper Devonian to Upper Jurassic, not differentiated on the geological maps, were recognised in this thick calcareous-dolomitic sequence with interbedded bands of black shales shales (Fig. 2).

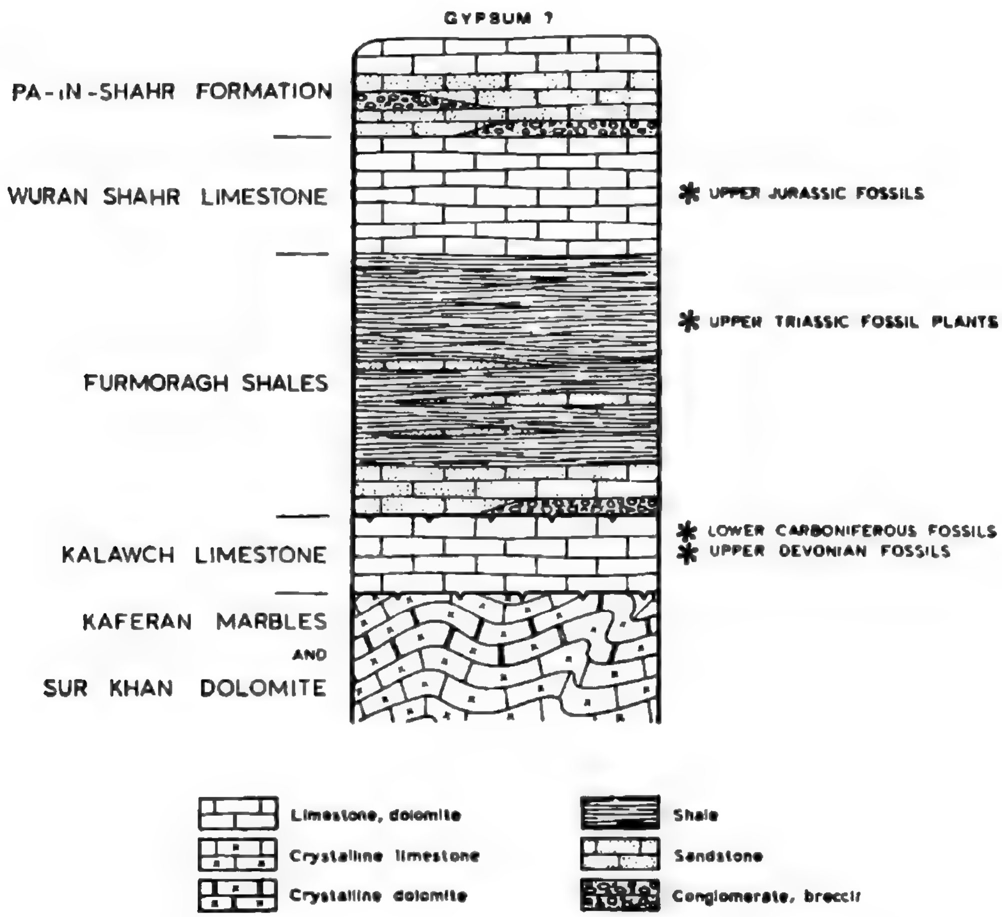

Fig. 2 - Schematic stratigraphy of the sedimentary formations in the area east of Faydzabad.

However, six different calcareous formations were recognised in the region east of Faydzabad although it was difficult to distinguish them and to determine their stratigraphic position due to the similar composition of some lithotypes and to tectonic dislocations. A stratigraphical study of the region located further to the north, where the tectonic structure could be less developed, may perphas allow more detailed stratigraphical sections to be observed.

The Pa-in-Shahr formation, one of the six lithostratigraphic units mentioned above, was nevertheless mapped and shown on the geological map at 1:150.000 scale. All the other units were only briefly investigated during our study but it was possible, however, to reconstruct their stratigraphical sequence which will be described in the next chapters. On the geological map attached to this volume, four of these formations have been grouped together and have the same colour (djl): two of them (Kaferan marble and Sur Khan dolomite) are partly metamorphosed and will be described in the chapter concerning the metamorphic rocks.

The three calcareous formations, clearly of sedimentary origin, were named as follows:

a) Kalawch limestone,

b) Wuran Shahr limestone,

c) Pa-in-Shahr formation.

Together with these calcareous formations there is a fossiliferous, sandy-argillaceous formation which has been provisionally named the Furmoragh shales.

2. DESCRIPTION OF THE FORMATIONS.

2.1. **Kalawch Limestone** (Kal).

It consists of a grey limestone, occasionally arenaceous, corresponding, at least to some extent, to the calcareous band outcropping to the east of the Wuran Shahr pass (3105 m) which is interposed between the two parallel black shale horizons. The limestone beds strike mainly north-south and while to the west they appear to be in normal contact with the black shales, to the east the contact is represented by a fault.

The fossiliferous locality (61 AP-5) where Pasquarè collected his samples (1), No. 2 on the attached geological map, is located three kilometres to the north of the pass and about one kilometre to the north of the peak mar-

(1) This fossiliferous locality was found just the day when Pasquarè, for political reasons (see page 8), was urgently recalled to Kabul by the expedition leader and therefore could not go back.

ked 3161 m. The elevation of the fossiliferous locality is 2820 m a.s.l., within the small valley on the western slope of the upper Kalawch valley.

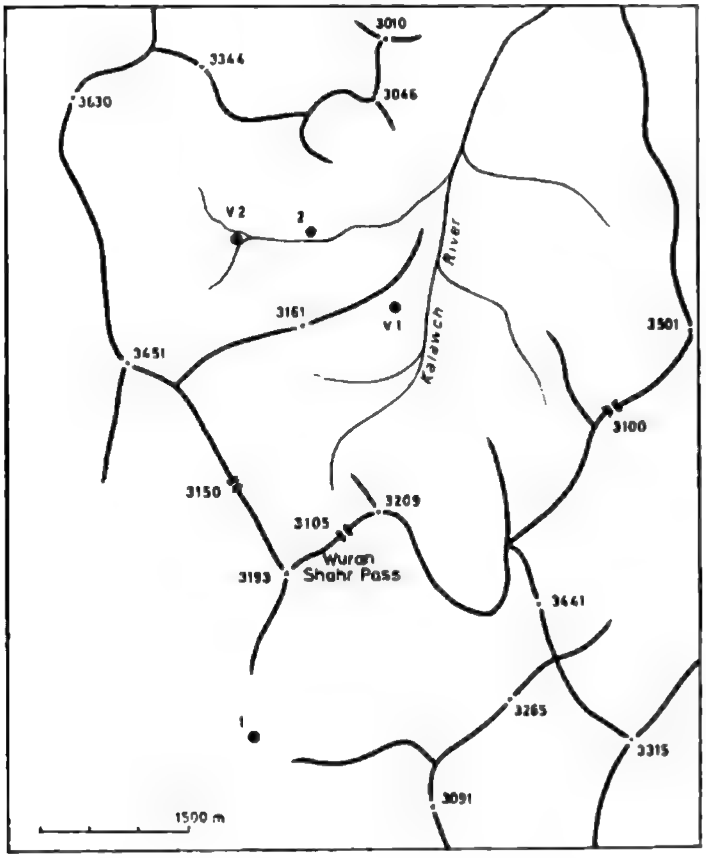

Fig. 3 - Fossiliferous localities in the area of Wuran Shahr Pass. 1 = Fossils of the Upper Jurassic; 2 = Fossils of the Upper Devonian; V1 = Fossils of the Lower Carboniferous; V2 = Fossil of the Upper Triassic.

The fossils were determined by C. Rossi Ronchetti who identified the following species:

Cyrtospirifer verneuili (Murchinson),
Cyrtiopsis davidsoni barrauxensis Grabau,
Camarotoechia sp.,
Productella sp.

Although the small fossil fauna (brachiopods) is poor, according to Rossi Ronchetti it is sufficient to prove that the Kalawch limestone belongs to the Upper Devonian.

R. Varvelli, a member of the « Afghan 65 » expedition, collected in the summer of 1965 a small fossil fauna with corals in a limestone very similar to the Kalawch limestone at a locality about one kilometre to the south-east of the previous one ([2]) (Fig. 3).

(2) This fossil locality is not represented in the geological map because it was discovered after its publication (1964).

The specimens which VARVELLI kindly sent to us were determined by A. VON SCHOUPPÉ who recognised the following species:

Fasciculophyllum multiseptatum von Schouppé,
Zaphrentites sp. ind.,
Caninophyllum tomiense (Tolmachev),
Amigdalophyllum ? kalawchense von Schouppé,
Michelinia ? sp. ind.

This fossil fauna also, as was the previous one, is very poor in species but does not belong, however, to the same age. It is more recent and must be assigned to the Lower Carboniferous.

According to the above data it appears that the lower part of the Kalawch limestone belongs to the Upper Devonian, its upper part to the Lower Carboniferous. It is also possible that the lowest horizons belong to older stages and the uppermost ones to younger stages since a stratigraphic section of this formation was not surveyed. Temporarily the Kalawch limestone can be divided into two members (the lithostratigraphic characters of which are not well known), that is a lower member of Upper Devonian age and an upper member of Lower Carboniferous age. The grey dolomite with crinoids (61 AP-4) outcropping near the mountain top marked 3451 m belongs perphaps to the latter member.

2.2. Furmoragh shales (and black slates) (Fbs).

GENERAL OUTLINE. — The name Furmoragh shales (and black slates) denotes a complex of schistose rocks which, apart from a different degree of metamorphism by which they can be differentiated, present many similarities and appear lithotypes of the same formation. The lithotypes outcropping to the east of Faydzabad are similar as are also those exposed to the west of the same town. In this latter area, due to better exposures, we also measured a stratigraphic section near Farkhar which we chose as the type-section of a formation created by us and called « Farkhar Slates » (page 47). Only this formation was mapped and it is shown on the attached geological map.

It was not possible to ascertain if the black slates outcropping in the two

areas are part of one formation. Moreover it is very probable that the black shales and slates consist of more than one formation.

In this paragraph all the rocks which in the field were provisionally mapped as black slates are combined together; on the geological map they are shown with the same colour (bs). It was not considered necessary to describe separately the fossiliferous black Furmoragh shales exposed in the Wuran Shahr pass area since it appers that they pass laterally to black slates as happens also at other localities (page 31). It was also thought advisable not to describe them in the chapter concerning the metamorphic rocks since the most interesting beds of this complex are the fossiliferous ones which have a shale facies. The most markedly metamorphic facies will be mainly described in the chapter concerning the Lake Shiwa area where these rocks are better exposed and differentiated. Regarding the name, which is to be considered provisional and is useful for stratigraphical references, it was chosen from a locality fairly distant from the outcrops of the fossiliferous beds since the only one available in that area (see maps) had been used for another formation. Furmoragh, nevertheless, is located near a large outcrop of black slates belonging to the beds which provided the fossil plant remains. This fact is not meant to infer that the beds exposed near Furmoragh correspond to the same horizon as the fossiliferous one. It must also be said that although the black slates outcropping in the area to the north of Furmoragh are lithologically similar to the Farkhar Slate, they cannot be identified with the latter formation since their age is considerably different as will be shown later page 32). It is however possible that the lower part of the Furmoragh shales, which is unknown, could extend upward to the Farkhar Slate which, as will be shown, is pre-Triassic.

Petrography. — The study of samples of black shales and slates revealed that they consist of three different rock types. The first are epimetamorphic rocks: fine-grained arenaceous shale and slate, arenaceous-chloritic-sericitic schist, and phyllitic slate. The second group is represented by pelitic, contact-metamorphic slate similar to a cornubianite with andalusite, cordierite, sillimanite, garnet, etc., and biotitic quartz-schist with the same minerals. The last group consists of polymetamorphic rocks such as biotitic and occasionally graphitic schists with one or more of the following minerals: garnet, staurolite, andalusite, and kyanite. The rocks of the three groups outcrop at random within both areas of black slates. The polymeta-

morphic group is exposed only in the eastern area, the other two groups being commonly present together in the same areas.

In this paragraph are described only the rocks belonging to the first group. The second and third groups, as already mentioned, will be discussed in the chapter dealing with the Lake Shiva area.

FIELD INVESTIGATION. — Although only limited data are available concerning the geological characteristics of the fossiliferous locality near the Wuran Shahr pass, this fossil occurrence is described first because of its stratigraphic importance (Fig. 3).

Fossil plant remains, partly well preserved, were collected by R. VARVELLI in several rock slabs during the « Afghanistan 65 » expedition ([1]).

These fossils were found in a black, schistose, pelitic and psammitic rock outcropping at the confluence of two small valleys about one kilometre to the north-west of the point 3161 m (and therefore 600 m to the west of the Upper Devonian fossiliferous locality) in the long belt of black shales extending for more than six kilometres to the north of the Wuran Shahr pass. The palaeontological determinations were carried out by P. D. W. BARNARD from Reading University who identified the following species:

Pterophyllum filicoides (Schloth.) Thomas
Pterophyllum kalawchiense Barnard
Otozamites ashtarensis Barnard
Taeniopteris pseudobrevis Barnard.

Besides a known form there are three new species. According to BARNARD this fauna belongs to the Upper Triassic ([2]).

The areal extent of the fossiliferous beds is not known; it can only be inferred that they form, at least in part, the long belt of black shales which extends north of the Wuran Shahr pass and south of it for about fifteen kilometres. Also the long bands of black shales, parallel to the previous one and orientated approximately north-south, exposed in the mountainous region to the north of Furmoragh appear to belong to the same formation.

To the north of Furmoragh, in the area investigated, the black slates

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(1) We wish to thank Dr. VARVELLI for releasing to us the important palaeontological specimens which he collected in Afghanistan.

(2) The description of this fossil fauna appeared in volume 2nd, series IV of the present collection.

are represented by black and grey-green slates and siltstone (61 AD-5,-6) with intercalations, occasionally frequent near the base, of ligth-grey to white, occasionally blackish quartzose sandstone (61 AD-7). The rock is generally intensely fractured.

Detailed data on the stratigraphic sequence are not available. It can be said, however, that its composition is very uniform although some variations are present. Uphill from the eastern end of the village of Pa-in-Shahr, for instance, light-grey, homogenous and massive, greyish when altered, fine-grained sandstone are the predominant rock type. Some darker beds, occasionally banded, are rich in biotite flakes; other beds contain lenses of microconglomerate with few pebbles dispersed in a matrix which is mainly cement. The rock is intensely fractured and the strike is variable although generally the beds dip 20°-40° to the north-northeast.

To the north-east of Furmoragh, along the caravan trail to the Lake Shiwa, these beds strike north-east with some deviations to the north. The beds are generally tightly folded and cut by transverse faults causing evident and recognisable change in the quartzite outcrop. Other faults and overthrusts are parallel to the strike of the beds. In the upper valley of the Darya-i-Shiwa, oriented approximately north-northeast, the black slates are folded in an asymmetrical anticline the eastern limb of which has gently dipping beds, the western limb steeply dipping and with occasional vertical beds.

The same formation, with similar lithological characteristics, has an extensive outcrop area in the Shakh Darrah river valley at least up to the confluence with the Darya Nakheir Par valley where an outcrop of plutonic rock outside the geological map attached to this volume, is present.

Further to the east the black slate outcrops continue at lenght with the same characteristics of these previoosly described. Also in the Lake Shiwa area beds of light-coloured quartzose sandstones are intercalated in the black slates; this fact, together with the continuity of their outcrops, is further proof that it is the same formation. Variations in the lithostratigraphic composition are represented by an increase in the more arenaceous facies towards east.

As previously mentioned, in this area the black slates underwent changes brought about by regional and thermal metamorphism. These effects will be described in the chapter concerning the Lake Shiwa area.

It must also be mentioned that a dyke of white quartz is present in the

black shales outcropping in the Shiwa valley, half-way between its headwaters and the confluence with the Shakh Darrah river.

The thickness of this formation is not known but it can be safely assumed to be more than 1000 m.

Age. — The presence of fossil plant remains of Upper Triassic age in the black shales exposed in the neighbourhood of the Wuran Shahr pass is not sufficient evidence for assigning the whole formation to this epoch. As previously said, the Furmoragh shales and the black slates have a thickness of more than 1000 m and therefore it is possible that several other older or younger stages are present in this formation, all the more so as it is not known in which part of the formation the fossiliferous beds are located.

In this connection it must also be mentioned that in the Wuran Shahr pass area, which appears to be the least affected by metamorphic phenomena, more fossiliferous localitites were found in the limestones overlying and underlying the belt of fossiliferous black shales described in the previous pages. The Kalawch limestone is present in the east, the Wuran Shahr limestone in the west. The first is of Upper Devonian and Lower Carboniferous age; the second of Upper Jurassic age. It is therefore reasonable to assume that the Furmoragh shales and the black slates were deposited between the Lower Carboniferous and the Upper Jurassic.

From what has been said before, it must not be assumed that the « black slates » represent all the stages, since hiatuses may exist in the stratigraphic sequence. Moreover it is not known if the black slate formation is complete in the investigated area since intense tectonic dislocations are present there.

Only more extensive investigations, especially in the area to the north of the studied one, can solve this problem.

2.3. Wuran Shahr Limestone (Wsl).

This consists of a black, microcrystalline, occasionally bituminous, generally laminated limestone interposed, as a long belt, between two bands of black shales and slates. In the west the Wuran Shahr limestone, steeply dipping to the west, is separated by a fault from the black slates which

show the same structure; in the east the limestone and the black slates appear to be in sequence. The beds dip steeply to the west and appear to overlie the Upper Triassic Furmoragh black shales already described in the previous paragraph.

At a locality in the upper Wuran Shahr valley, about two kilometres to the north-east of Wuran Shahr-i-Pa village (fossiliferous locality No. 1 of the geological map), PASQUARÈ collected some fossils among which ROSSI RONCHETTI identified the following species:

Ctenostreon proboscideum Sow.,
Pholadomia canaliculata Roemer,
Pinna sp.

It is a poor fauna, but sufficient, however, to assign the Wuran Shahr limestone to the Upper Jurassic. The fossils were found in a black, occasionally powdery, generally laminated, microcrystalline limestone about 800 m from the contact with the nearest black slates and at 2470 m a.s.l. on the rigth hand slope climbing to the Wuran Shahr pass (67 AP-1).

Beyond the Wuran Shahr pass, at 3200 m, on the left hand slope near the head of the large intramontane basin between the peaks marked 3451 and 3193 m, almost in contact with the black slates, are outcrops of yellow-grey and grey-brown, generally oolitic, flaggy, microcrystalline limestone with very irregular texture which generally have abundant larger foraminifera or fragments of macrofossils (61 AP-2). Just above them there are light-grey, massive limestones also microcrystalline and with horizons containing larger foraminifera (61 AP-3). These latter limestones represent the continuation of the horizons overlying the band exposed at the previous fossiliferous locality. In the first large valley to the north of the Wuran Shahr pass, left side tributary of the Darya-i-Kalawch, descending from the peaks marked 3451 and 3161 m and just below the latter one, outcrop black, cryptocrystalline limestones generally with calcite veins (61 AP-150).

The quartzites located just below the previously mentioned peaks, are generally massive and light-green in colour (61 AP-151). Near the base some of them are fossiliferous (61 AP-6).

Also near Sar-i-Hauwidz are present black, well bedded, generally laminated limestones with calcite veins (61 AP-159).

2.4. Pa-in-Shahr Formation (Pf).

The upper unit of an evaporitic rock sequence outcrops at the confluence of the Kalawch and the Shiwa valleys, along the Wurhel valley, in the valley of Syah-Jar and on the lower right hand slopes of the Kokcha valley between Pa-in-Shahr (Rabat—Baharak) and Furmoragh. This formation consists of yellow, crystalline limestone with gypsum nodules; red, powdery, limonitic limestone; cellular dolomite; grey and brown limestone; and grey, marly limestone with large crystals of scapolite.

This evaporitic formation was mapped in the field and is shown (Pf) on the geological map. As it can be seen, the eastern outcrop presents beds steeply dipping to the east-northeast and is interposed between the Furmoragh black shales, strongly fractured and dipping 20° - 40° to the north-northeast, and light-grey to whitish, occasionally banded limestones in distinct beds 10-30 cm thick (61 AP-78).

The Pa-in-Shahr formation is represented here by gold-yellow, yellow-brown and straw-yellow, cellular, powdery, crystalline limestones. The limestones contain curious stick-shaped inclusions and beds of variegated limestones (generally grey and white) rich in contact-minerals (61 AP-74, -75, -76, -77).

A more varied sequence of lithotypes was observed on the western slope of the Pa-in-Shahr valley. Near the contact with the black slates, grey and generally, especially in the upper parts, yellow, yellow-orange and brown-reddish, concretionary and cellular limestones in very thick beds 61 AP-144) are prevalent. Other grey and banded limestones form narrow belts near the contact with the black slates and contain contact minerals 61 AP-145).

At the base of these limestones, at an elevation of about 1700 m, are exposed grey or grey-brown, granular quartzites (61 AP-146) overlying conglomerates of different types consisting of grey, ash-grey, white-yellowish and red-brown pebbles of crystalline limestones in an abundant, arenaceous, fine-grained, quartzose matrix the grains of which are generally laminated and have streaks of mica (61 AP-147). In the latter rock-type thin beds of grey-green, coarse sandstone are intercalated (61 AP-148). At the top of this sequence, the yellowish and red concretionary limestones locally contain angular fragments 5 to 30 cm in diameter of grey, generally banded limestones,

Near the lower end of the Kalawch valley, the evaporite sequence shows frequent breccias consisting of different size angular fragments, generally banded, of black limestones (61 AP-151, -152, -153, -154).

No fossils were found in the Pa-in-Shahr formation. This fact and the strongly dislocated outcrop area make it very difficult to assign an age to this formation.

Some stratigraphic indication and some similarities with the upper member of the Karkar Formation in Kataghan, with evaporitic facies, induce us to refer (with uncertainty) the Pa-in-Shahr formation to the Upper Jurassic.

2.5. Summary of the Stratigraphic Sequence East of Faydzabad.

We summarize within the table 1 (page 36) the sequence of lithostratigraphic units which we met during our rapid investigation in the area east of Faydzabad.

The table marks out an incomplete stratigraphic sequence, with large gaps, some of them undoubtely depending on lack of field investigation, others probably beeng original gaps in the sedimentary process.

A recent report by I. V. Arkhipov, J. G. Leonov & A. A. Nikonov (1970), summarizing the present geological knowledge on the Badakhshan, reports the existence in our country (besides the formations already mentioned) of a marly-argillaceous formation to be referred to the Lower and Middle Triassic for its affinities with the Pamir formations. We lack of details on that formation: probably it deals with a portion of the sequence included by us under the general name of « black shales ».

Stratigraphic units of different age are also pointed out in Badakhshan, but they crop out outside of the central part of it.

2.6. Comments on the Stratigraphy of the Sedimentary Formations East of Faydzabad.

As seen in the preceding pages, the sedimentary formations of normal facies distinguished in the area east of Faydzabad, comprise a wide series

Table 1.

Central Badakhshan east of Faydzabad	Environment	Age	Central Pamir	Afghanistan and NW Pakistan
Pa-in-Shahr formation (Psf) (evaporitic)	lagoonal	Upper Jurassic	(Fossiliferous limestone)	Karkar formation (Member B)
Wuran Shahr limestone (Ws l) with pelecypods	neritic	Upper Jurassic	Fossiliferous black limestone with shales intercalations of Akbaital	Karkar formation (Member A) (Desio, Cita & Premoli Silva, 1965)
Furmoragh black shales and slates with fossil plants	continental	Upper Triassic	Fossiliferous dark shales and slates with plants	? Lower Saighan sequence
Black shales siltstone and sandstone (limestones ?)	?	? From Middle Triassic to Upper Carboniferous (no fossils)	Marbly-argillaceous sequence	Fusulinid limestone of Shogram (Desio, 1966)
Upper Kalawch limestone (Kal) with corals	marine	Lower Carboniferous	Fossiliferous limestone of Akbaital	Lun shales (Reshun)
Lower Kalawch limestone (Kal') with brachiopods	marine	Upper Devonian	Fossiliferous limestone of Jasgulem and Wanch	Shogram Formation (Desio, 1966) Hajigak Limestone (Martina, 1963)

of lithotypes which range in age from the Upper Devonian to the Upper Jurassic. At this point it might be asked, if the various formations were arranged in chronological order whether they represented a continuous and complete stratigraphic series in the area of their outcrop. Undoubtedly a certain continuity seems to exist between the various formations which in the area around the Wuran Shahr pass are distributed with an apparent regularity in ascending succession proceeding from east to west, that is starting from the oldest in the east and passing towards the west into younger formations. If the hypothesis is valid it is possible then to reconstruct the stratigraphic series of normal sedimentary facies in the area situated to the north of Furmoragh, in the following way, starting from the base:

1) Kalawch limestone:
   a) grey limestone, sometimes arenaceous, with Upper Devonian brachiopods,

b) grey limestone with Lower Carboniferous corals;

2) Furmoragh black shales with Upper Triassic fossil plants;

3) Wuran Shahr limestone, black, microcrystalline, sometimes bituminous limestone with pelecypods of Upper Jurassic age;

4) Pa-in-Shahr formation: represented by an evaporitic sequence mainly composed of yellow crystalline limestone with nests of gypsum, red powdery limonitic limestone and grey marly limestone with large crystals of scapolite probably belonging to the Upper Jurassic.

It was not possible to identify eventual stratigraphic breaks between the various members of this marine stratigraphical series, apart from those indicated by the continental plants of the Upper Triassic, and probably also by the conglomeratic and quartz sandstone horizon at the base of the Furmoragh formation; also the thickness of the individual formations is unknown but when taken together they must be less than 3500 m. It must be added that since formations younger than the Pa-in-Shahr formation are missing, taking account of the lagoonal facies, one concludes that with this unit the marine cycle in the area examined to the east of Faydzabad, was terminated.

However, it must be remembered that from our research we posses only fragments of the regional stratigraphic sequence, which thanks to the presence of fossils can be arranged in a logical order as in the table 1. Nevertheless, during the long interval between our expedition and the publication of the present work several short geological accounts have emerged which deal with the stratigraphy of Badakhshan and of which account must be taken. A comparison with the better known stratigraphic series in Pamir, could also be very useful since the area surveyed by us is directly connected tectonically (Desio, 1965 a).

The works which have already been indicated are the summary report of the geological knowledge of Badakhshan by I. V. Archipov, I. G. Leonov & A. A. Nikonov (1970) which summarises as far as Badakhshan is concerned, the note by S. K. Mirzod, V. P. Kolchanov & O. A. Manucharjantz (1968), which in its turn is a sort of synopsis of the relative knowledge of the whole of Afghanistan, with particular emphasis on the mineral deposits. The Archipov et al. report in which attention has been drawn to our preliminary re-

ports contains a geological and tectonic sketch-map on a small scale (1:3 millions) together with a very brief account of the correlation of Pamir with all of Badakhshan.

From the two accounts cited above an attempt has been made to extract the elements concerning the sedimentary stratigraphy of Badakhshan east of Faydzabad, especially that part which we did not identify and which perhaps does not even outcrop in the area we explored.

The oldest fossiliferous sedimentary formations in Badakhshan, according to the account given by Mirzod et al., are the « Ordovician sandstones » more than 300 m thick with trilobite remains which are probably referable to the species *Basiliscus nobilis* Barr., which outcrop concordantly above a dolomite, limestone, sandstone, siltstone and argillite complex more than 700 m thick which may be Cambrian in age. This age assignment was made by G. G. Semenov, based on correlations with the stratigraphic sequence of Central Pamir, but no other details or bibliographic information are available to enable us to understand the location of the outcrops and the stratigraphic succession, to seek eventual equivalents among the formations examined.

It can only be presumed that they form a part of the most eastern outcrops of Badakhshan, among which they are included under the generic name of « pre-Cambrian formations perhaps in part Lower Palaeozoic and Palaeozoic » and they cannot form part of the tectonic unit of which the area east of Faydzabad is a part. For this reason, it is not probable that these formations are present in the area considered here.

No records of the existence of the sedimentary Silurian in Badakhshan are known. In the notes cited above, the possible presence of beds of this age are suggested in the lower part of Durumbak formation on the northern side of the Hindu Kush, but it is believed that it concerns the outcrops in the Surkhab valley south-west of the area considered.

The presence of the Devonian sequence in Badakhshan is not mentioned in the reports in question apart from the data published by us previously (Desio, Martina & Pasquarè, 1964 a).

As far as the Upper Palaeozoic is concerned, the two reports mentioned above give important details about Badakhshan.

In western Badakhshan, as in Pamir and Darvaz, according to Archipov et al., the Lower Carboniferous is present and in part — it seems — the

Middle represented by clastic volcanic formations not less than 4-5000 m thich, and the Middle and Upper Carboniferous by limestones only several hundred metres thick. The Lower Permian is composed of limestones, sandstones, and shales 2500 - 3000 m thick, the Upper Permian principally by red formations of notable thickness. The remarks applied to the older formations can also be applied to these formations. In the sketch map by ARCHIPOV et al. the « Lower Carboniferous volcanic series » is distinguished and occupies a western position, very close to the fault which separates Badakhshan from the Upper Amu Darya Depression. This position amply justifies the fact the we have not encountered formations of this facies, which — it might be added — are presumably missing in Badakhshan east of Faydzabad.

In Central Badakhshan, the area in which we were most directly occupied in the preceding pages, the three authors record two series in the Upper Palaeozoic, a lower arenaceous-argillaceous series, at least 2-3000 m thick, and an upper unit, essentially Permian, comprising 300-350 m of dark limestone.

The information given by MIRZOD et al., does not correspond exactly. In connection with the Permian of Central Badakhshan it should be remembered that G. G. SEMENOV and colleagues on the basis of correlation with Northern Pamir distinguished precisely the two stratigraphic subdivisions which attain a thickness greater than 3000 m and are composed mainly of limestones with intercalations of carbonaceous-argillaceous shales, sandstones, conglomerates and tuffaceous rocks. Certain elements seem to indicate that in single « facies-structural zones » the Permian deposits were intensely and structurally metamorphosed presenting gradual transitions, for exemple, to phyllites and gneiss. The above mentioned authors add that « in this case it cannot be excluded that certain metamorphic formations first referred to the pre-Cambrian (for example the Rabat gneiss) are actually of Permian age ». This will be dealt with in another paragraph.

If we pass to a comparison with the succesion mapped by us, in the Kalawch limestone formation, apart from the Upper Devonian, the Lower Carboniferous is also present, as we know, both fossiliferous, but with different facies as mentioned above. It is moreover possible that in the Kalawch limestone the Upper Carboniferous is also present, even if we have no proof.

No proof has been found either for the presence of Permian strata,

which however may be represented also in the upper limestone complex of Kalawch and at the base of the Furmoragh shales.

From what has been read in the note in question no Permian fossils have been found in Central Badakhshan: the attribution of this age to the beds described has been based on the comparison with Northern Pamir, and this leaves doubt about the determination.

On the lateral passage from normal facies to metamorphic facies, we also have recognised the transitions from black shales to black slates, while we do not share the opinion of the three authors cited above that the Rabat Gneiss can be a Permian metamorphic facies.

When they refer to the Mesozoic strata, the three authors record that the area of major development is represented by Central Badakhshan, where a uniform silty-argillaceous-phyllitic formation, more than 2000 m thick is attributed by analogy with Pamir, to the Upper Triassic—Lower and Middle Jurassic. These are evidently our Furmoragh black shales and slates in which VARVELLI found terrestrial fossils of Upper Triassic age. It does not seem probable that the formation comprises the Middle and Upper Jurassic also, because this is contradicted by the presence of the limestones of the Wuran Shahr formation with marine fossils of Upper Jurassic age and of the Pa-in-Shahr formation of lagoonal character.

In western Badakhshan, the Mesozoic formations are found in a single locality near Dashtidzhum, in Tadzhikistan territory, in the fracture zone which separates Pamir from the Upper Amu Darya Depression, where conglomerates and grey sandstone of the Lower and Middle Jurassic are represented, together with Upper Jurassic gypsum and « red rocks » of Lower Cretaceous age. It is perhaps possible to identify here also, our Pa-in-Shahr evaporitic formation and consequently the upper Karkar Formation, while the clastic formation of the Lower and Middle Jurassic seems to correspond to the Saighan Formation. In the Dashtidzhum area, therefore, in regular succession there are representatives of the Saighan Formation, the upper Karkar Formation and the « Red Grit », that is formations which have their widest distribution south-west of the territory considered here (east of Faydzabad) and in greater part outside Badakhshan. This fact is clearly related to the tectonic position of the Dashtidzhum area with respect to Badakhshan (DESIO, 1965 a). The first is located in a tectonic zone to the west of the one in central-eastern Badakhshan which includes the area east of Faydzabad.

Regarding eastern Badakhshan, Archipov, Leonov & Nikonov mention the dark slates outcropping between Zebak and Ishkashim which correspond to the Triassic part of this latter locality in Pamir. Red conglomerates of uncertain age, which will be described in the paragraph concerning the Zebak region, overlie the slates discordantly.

The Russian authors mention also other younger formations which, as it will be shown later, outcrop in western Badakhshan and especially in Kataghan region.

The five formations which were previously established representing the Upper Devonian, the Lower Carboniferous, the Upper Triassic and the Upper Jurassic have probably to be joined together with one or more formations of Upper Carboniferous and Permian age. These formations, consisting of interbedded limestones and carbonaceous shales, sandstones and conglomerates, are logically interposed between the Kalawch limestone and the Furmoragh black shales and slates; it is possible, as mentioned above, that parts of these two formations include also horizons belonging to the Upper Carboniferous and the Permian. In this case the sequence would be without breaks from the Upper Devonian to the Upper Jurassic.

Nothing can be said, on the other hand, about the presence of horizons with sedimentary facies older than Upper Devonian for which no satisfactory evidence has been found up to now.

In conclusion, the stratigraphical relationships, besides the tectonic ones already known (Desio, 1965 a), between the Central Badakhshan east of Faydzabad and Central Pamir are quite clear.

Further evidence could be found if all the various formations present in the latter area were investigated in detail, although that is unnecessary considering the evidence given in the previous pages. Nevertheless, we wish to quote here a letter, dated 7th October 1965, sent to A. Desio by D. Nalivkin with his comments about the Geological Map of Central Badakhshan (1964) of which he had received a presentation copy:

« Many times I think about the cause of close connection of limestone (of) such different ages, which we see in (the) division "djl". From (the) inserted little map of the tectonic position (it) is possible that (the) division "djl" is connected with "intensively tectonised bands". If it is so, these bands are going to Bartang river, along this river and Sarez lake to Ak Bai-

tal pass, through all Central Pamirs. I studied this band or bands in the region of this pass. They are extraordinary.

Blocks of Silurian shales and limestones, Upper and Middle Devonian limestones, Lower Carboniferous limestones, Upper Paleozoic (mostly Permian) limestone, sandstones and shales, Upper Jurassic limestones, all with typical faunas, Cretaceous red beds and Upper Cretaceous intrusives, all mixed without order, how in "vineyard". I give to this band the name "Ak Baital zone of overthrusts". (It is) interesting that this zone corresponds to the zone of earthquakes with very deep epicentres, 200-300 kilometers by the data of Soviet seismologists. It is possible that the main faults, connected with this zone, are going to such depth (uppermantle).

I think that N. N. LEONOV is not right. Alai and Hissar ranges are Hercinian structures. They are divided from alpinian Pamirs structures by very long and big main fault, active seismologically ».

This is the interesting letter sent by NALIVKIN. It has to be made clear that the symbol *djl* in the Geological Map of Central Badakhshan includes the following formations: Wuran Shahr limestone (Upper Jurassic), Sur Khan limestone, Kaferan limestone and Kalawch limestone (Upper Devonian). At that time the presence of Lower Carboniferous fossils in the Kalawch limestone and of Upper Triassic fossils in the Furmoragh black shales had not been ascertained yet. The latter rock-type had provisionally been included in the « Black slates » (*bs*).

An examination of the various outcrops of Upper Devonian age in Central Pamir (BARKHATOV, 1963) shows that there are lithotypes, similar to the Kalawch limestone, represented by the limestones outcropping on the southern slope of the Jasgulem range, in the Vadut valley, where D. V. NALIVKIN (in BARKHATOV, 1963) collected, among other fossils, specimens of *Cyrtospirifer verneuili* Murch., *Camarotoechia* and *Productella* which could also be present in the Badakhshan fossiliferous locality (1). Such similarities are also shown by the limestones outcropping along the Vanch river which contain not only the species mentioned above but also the species of the other two genera present in Badakhshan.

Regarding the Lower Carboniferous it can be said, according to S. S. KARAPETOV, that in Akbaital the limestones of this age concordantly overlie

(1) The specimens are too poorly preserved for to be determined specifically.

limestones of Upper Devonian age, which appears to be the case in Badakhshan. Also the tectonic pattern of the Jasgulem range, as in Akbaital, is characterised by intense reverse faulting with the development of tectonic slices similar to what occurs in Central Badakhshan, in the area north of Furmoragh.

The Upper Carboniferous of the Akbaital region is also represented by fossiliferous calcareous facies (mostly brachiopods) so that this horizon too could be present in the Upper Kalawch limestone of Badakhshan.

The lithological composition of the Permian of Central Pamir is much more varied but its exposures are irregular. In the Sarez region it is represented by slates, arenaceous slates and sandstone with calcareous intercalations containing some fossils of Lower Permian age. In the Muskol-Rangkul area the Lower Permian consists of fusulinid limestones which are missing in the Jasgulem region where the Devonian limestones are overlain by marly-calcareous beds of Lower Triassic age.

There are then considerable breaks in the Permian sequence of Central Pamir and therefore it can be assumed that also in Central Badakhshan, to the east of Faydzabad, the Permian or most of it was never deposited.

The fossiliferous Furmoragh black shales of Upper Triassic age correspond to a similar facies of Central Pamir where such stage is just represented by dark coloured shales and slates, occasionally carbonaceous, associated with fine- and medium-grained sandstone with fossil plants belonging for the most part to the *Pterophyllum* (Barkhatov, 1963); this genus is present (with two species) among the fossils found in Badakhshan. In Central Pamir this flora was assigned to the Carnian stage but the above mentioned formation represents the whole Upper Triassic. It is possible that the same is true also for Badakhshan where, to the north of Furmoragh, thick sequences of black shales and slates are known to be present. Moreover it must be mentioned what Barkhatov said regarding this formation in Pamir, that is: « a weak regional metamorphism is normally characteristic in the Upper Triassic rocks: this notwithstanding the contact metamorphism gave rise in these rocks to schists and also to gneisses ». Similar observations, which will be reported in another paragraph, were made in the investigated area.

These facts too prove that there is an evident continuity between the Upper Triassic outcrops of the Furmoragh black shales and slates with fos-

sil plants exposed near the Wuran Shahr pass and schistose formation of Central Pamir.

Another outcrop of black slates located in the neighbourhood of Namangut, near the south-western end of Pamir, can be correlated with the black slate outcrops of Badakhshan which are also close geographically. In Pamir N. A. KHOREV (1956) found a fossil flora of Upper Triassic age which can be correlated with that found in the investigated area.

The Wuran Shahr limestone of Upper Jurassic age will be examined now. The Upper Jurassic marine beds of Pamir more similar to those of Badakhshan appear to be those outcropping near the Akbaital pass where black limestones with intercalated shales are exposed with a Callovian fauna. A lagoonal formation corresponding to the Pa-in-Shahr formation is missing in Pamir. The Pa-in-Shahr formation could correspond only, as far as age is concerned, to the volcanic formations outcropping in the southern part of Central Pamir.

Although the data gathered on the stratigraphy of the sedimentary formations in the area to the east of Faydzabad are not complete, the correlations established on the basis of these data with the formations known up to now in Pamir, only the younger horizon (evaporitic) is missing. This may indicate the beginning of a differentiation in the paleogeographic evolution of the two areas: the area we investigated appears to be more similar to North Pamir, the Upper Amu Darya Depression and, to the south-west, to the Kataghan region where, as already known, the upper part of the Upper Jurassic is represented by an evaporitic formation.

On the whole this short examination of the stratigraphic sequences of Central Pamir confirms their relationships with the investigated region although some differences consisting of the absence of some important horizons, are present, i.e. those representing the Permian. In this connection it must be remembered that NALIVKIN in his letter and BARKHATOV (1963) said that seldom complete sequences are to be seen in Central Pamir and often the various formations, mainly of Palaeozoic age, belong to tectonic slices, imbricate structures and fault-blocks more of less separated. What was said above leads to the assumption that also in our area similar conditions exist. It should, moreover, be assumed that in the investigated area the tectonic features are better developed (DESIO, 1965 b) since all the formations present in Central Pamir are also exposed in the much smaller area of Badakhshan.

β. AREA WEST OF FAYDZABAD.

In the region to the west of Faydzabal in Central Badakhshan and eastern Kataghan, the various formations are represented by a series of beds which are more complete than those in the eastern region because the tectonic structure involves folds which are broader and less disturbed by faults. Also in this region the sedimentary formations lie with an angular discordance on a crystalline basement, generally represented here by the Farkhar Slate, which shows low grade metamorphism.

The sedimentary formations of the area situated to the west of Faydzabad are of normal facies except the epimetamorphic Farkhar Slate, and have been mapped in greater detail, thus they represent well defined units. They are listed below in chronostratigraphic order, starting with the oldest. The Pleistocene continental deposits have been omitted from the list, except for the Taluqan Gravel, but are described in the chapter dealing with the Pleistocene.

a) Farkhar Slate,

b) Shinghan Conglomerate,

c) Qara Bulaq Sandstone,

d) Gazestan Formation,

e) Mashad Limestone,

f) Mohammed Aba Sandstone,

g) Baba Darwes Formation,

h) Bluti formation.

i) Kokcha Formation,

l) Taluqan gravel.

As mentioned previously some of these formations are coeval and pass laterally, more or less gradually, from one to another. The order of succession, therefore, from top to bottom does not correspond exactly to the chronostratigraphic succession as one would gather from Fig. 4.

The sedimentary formations which overlie the Farkhar Slate are not al-

ways the same; generally they are the Shinghan Conglomerate, the Qara Bulaq Sandstone and the Kokcha Formation.

As far as the age is concerned they range through from the Middle and Upper Jurassic, Lower and Upper Cretaceous, Palaeocene, Middle — Upper Eocene to Neogene. Many formations in the region to the west of Faydzabad have yelded identifiable mega and microfossils from which it has been possible to determine in some cases with precision, in others approximately, the ages of the units.

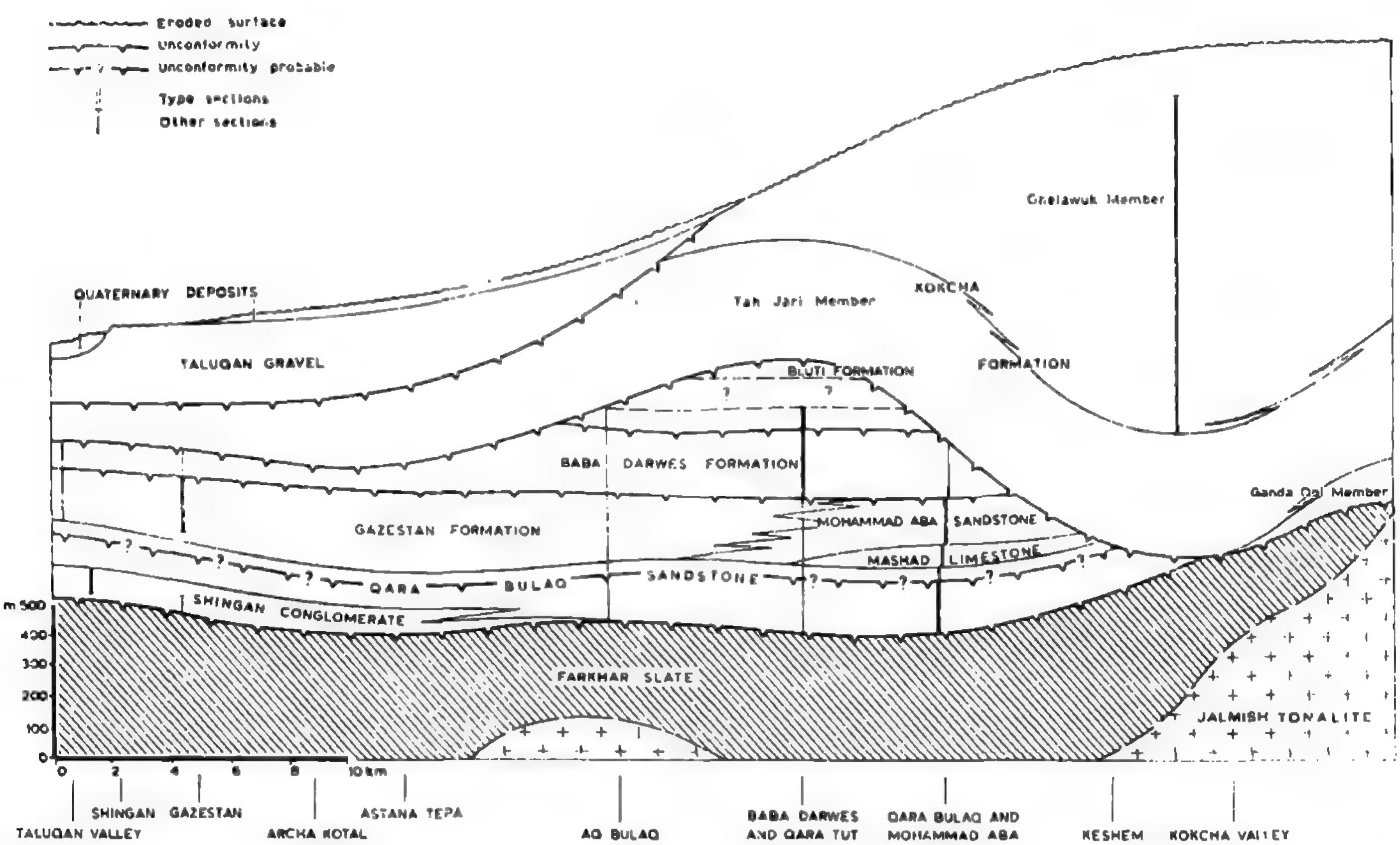

Fig. 4 - Scheme of the sedimentary formations west of Faydzabad.

In the list of lithostratigraphical units which compose the formations the fossils are mentioned, but a more extensive palaeontological documentation can be found in the second volume of the fourth part of this present series. However, in the appendix to the present chapter there is a description of the microfacies in which the results of the micropalaeontological studies of various samples necessary for the better interpretation of the lithotypes and a list of the fossiliferous localities with their contents are presented.

2. DESCRIPTION OF THE FORMATIONS.

2.1. **Farkhar Slate** (Fs).

Introduction. — In the Kokcha valley downstream from Faydzabad in the upper Hazara valley, and in the valleys of Wakhshi, Mashad and Farkhar, under a cover of Mesozoic and Tertiary (and Quaternary) deposits are extensive outcrops of a considerable thickness of dark coloured more or less well metamorphosed rocks. These rocks which are also in contact with the Jalmish Tonalite, the Kakhan Quartz Diorite and the Petwan Blastomylonite, are represented predominantly by dark arenaceous slate, black calcareous slate, quartzite and some conglomerate and sandstones.

This unit has been called here the *Farkhar Slate*, after the valley in which this rock complex outcrops with very considerable thickness exposed over a large area. It represents a true formation because of its relatively uniform lithological composition. These rocks are very similar overall to the black slates and shales widely distributed in the Hindu Kush, western Karakorum and Pamir region (Wakhan Slate, Misgar Slate, Singhie Shales etc.), but they resemble more closely those outcropping in the area to the east of Faydzabad (Shiwa valley, Jurm valley). These, however, show — at least in part — facies slightly less metamorphosed than the Fakhar Slate lithotypes and that is why the two rock groups mentioned above have been distinguished here, also as will be discussed later, because of their different ages.

Type-Section. — A stratigraphical section was surveyed in the Farkhar Slate in the Khurmab valley, between the villages of Farkhar to the west and Ardi Shan to the east (Fig. 5). The geographical coordinates are 69° 61′ east Long., 36° 34′ north Lat. The section starts from the alluvium of the Farkhar river, passes over the mountain called Koh-i-Shagarak (1291 m), immediately above and the east of Farkhar village where it continues along the right hand side of the Khurmab river valley until it encounters the Jalmish Tonalite, just before Ardi Shan is reached.

From the top to the base the rock stratigraphical sequence is as follows (from east to west):

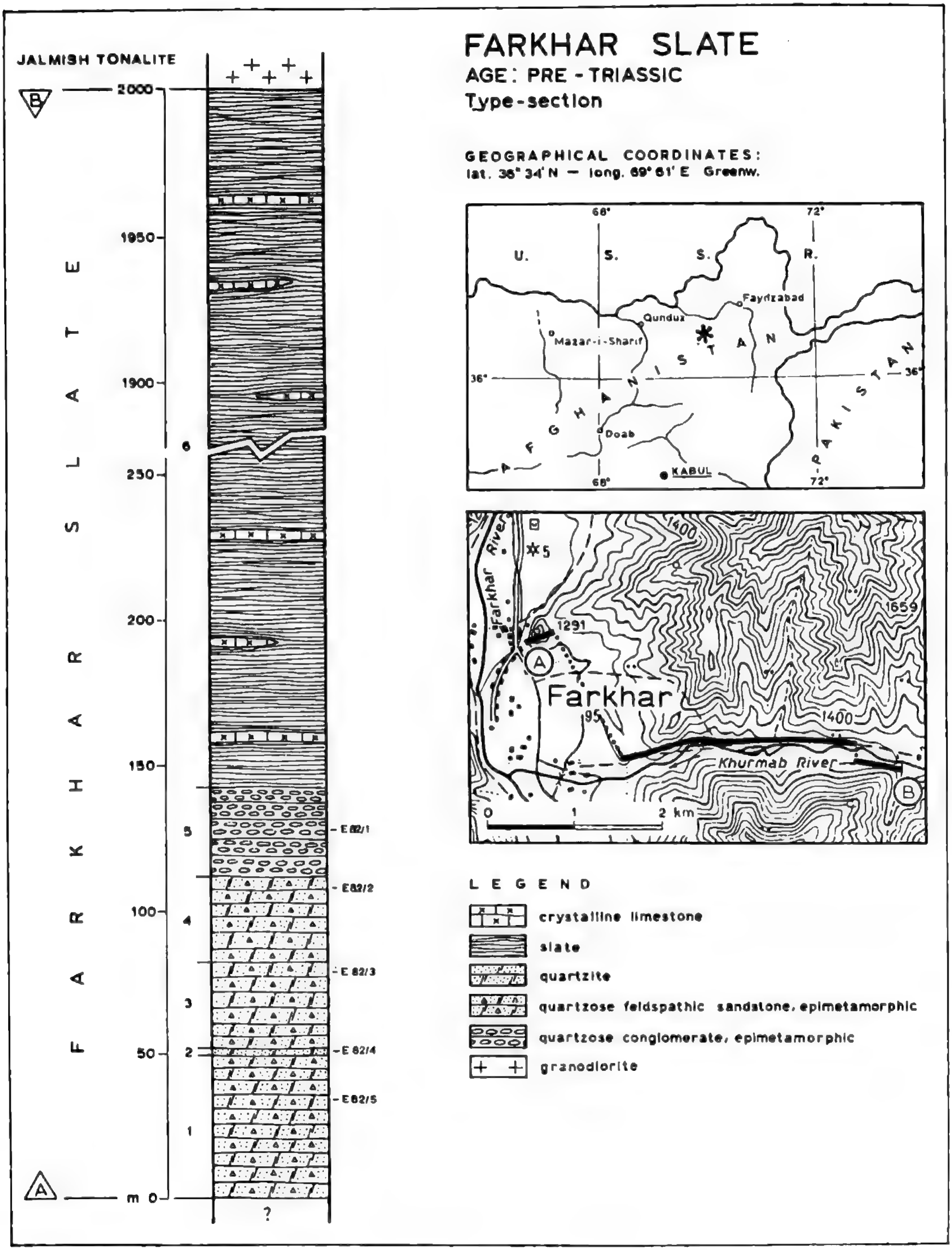

Fig. 5 - Type-section of the Farkhar Slate.

— Jalmish Tonalite; the contact dips to the west at 45°.

6) monotonous fine-grained arenaceous quartz-sericite slate both black and greenish in colour, with interbedded calcareous slate, about 2000 m;

5) Very compact epimetamorphic quartz conglomerate, reddish-grey in colour (61 AE-82/1) with fragments of quartz (prevalent) and black slates, a few centimetres in diameter, 30 m;

4) Epimetamorphic quartzose-feldspathic fine-grained sandstone grey-green in colour (61 AE-82/2), 30 m;

3) Epimetamorphic quartzose-feldspathic sandstone grey-green in colour (61 AE-82/3) (30 m thick);

2) Laminated quartzite (61 AE-82/4), 2 m;

1) Epimetamorphic quartzose-feldspathic sandstone (61 AE-82/5) purplish and reddish in colour, 50 m;

— Farkhar river Alluvium.

In the Farkhar section the Farkhar Slate is more than 2150 m thick. It appears to outcrop also, at least in part, on the mountains which form the western side of the Farkhar valley. The beds dip towards the east with dips which increase from the west (at Farkhar village the dip is 30°, 3 km away 45°). Near the contact with the Jalmish Tonalite the Farkhar Slate dips steeply (60°- 80°) towards the east. The contact surface however dips towards the west at 45°. Units 1 to 5 inclusive in this section compose the Kho-i-Shagarak (1291 m) which rises to the east above the village of Farkhar. In particular, unit 5 (the epimetamorphic quartzose conglomerate) outcrops right at its summit and the beds dip towards the east at 30°.

Areal Distribution and Stratigraphical Position. — Throughout the extensive outcrop area the Farkhar Slate displays a monotonous sequence oflithologies invariably dark grey or dark grey-green in colour, with a predominant amount of fine-grained arenaceous quartz-sericite slate and arenaceous quartzose feldspathic slate. In the valley of the Shor river, near Gazestan, Idel and Astana Tepa, the Farkhar Slate is overlain discordantly by the Shingham Conglomerate, while in the area between Kalafghan and Kishem, it is covered invariably with an angular discordance by the sand-

stones of the Qara Bulaq Formation. In the Farkhar valley also (in the Shinghan area) the Farkhar Slate underlies the conglomerates and sandstones of the same Shinghan and Qara Bulaq formations, but the visible contact, at least on the right side of the valley, is a fault. In the region further to the north, between Kishem and Tughak (in the Kokcha valley, 30 km west-northwest of Faydzabad), the Farkhar Slate is overlain invariably with an angular discordance by the youngest deposits of the Kokcha Formation (Neogene).

The eastern limit of the Farkhar Slate outcrop area between the valleys of Farkhar, Mashad, Hazara, and Kokcha, is marked by its contact with igneous rocks of the Jalmish Tonalite, the Kakan Quartz Diorite, and in the valleys of Mashad and Hazara also by mylonitised and blastomylonitised rocks (Petwan Blastomylonite).

In the Mashad valley, a kilometre to the south of Darrah-i-Shab Baba, the Farkhar Slate can be seen with a contact aureole, injected by leucogranitic material from the Jalmish Tonalite, which, a kilometre to the west of Darrah-i-Jim, penetrates the Farkhar Slate with a massive dyke several tens of metres thick and several hundreds of metres long.

However in the same Mashad and Farkhar valleys occasionally the Farkhar Slate appears underneath the Jalmish Tonalite as a result of local tectonics because the strongly folded beds are overturned and lie under the igneous body mentioned above (see the geological sections).

Remarks. — On his geological maps on a scale of 1:250.000 C. Hinze (1964) indicated the conglomerate of the Farkhar formation as a Jurassic deposit of continental facies, interpreting it as a southerly extension of the outcrops situated a few kilometres north-west of Farkhar, near Shinghan. In this connection it must be mentioned that among the rocks which compose the pebbles of the Jurassic Shingan conglomerate (see Shingan Conglomerate), granodiorite pebbles are found, whereas they are completely absent in the conglomerate of the Farkhar Slate (unit 5). Moreover, this latter unit is epimetamorphic whereas the Shinghan Conglomerate is not.

Age. — Although the formation does not contain fossils its age can be partly determined from its relationships with the rocks with which it is in contact. We have observed in fact how it is regularly found below all the local sedimentary formations of known age. Thus near Gazestan, Idel and Asta-

na Tepa it is discordantly overlain by the Shingan Conglomerate of Jurassic age, which is of particular interest since it is the oldest formation outcropping in the territory mapped during this study to the west of Faydzabad.

We have discussed above (page 49) the relationships between the Farkhar Slate and the Jalmish Tonalite, from which it is clear that the slate formation is older. The age of the Jalmish Tonalite was determined using radioisotopic methods (Desio, Tongiorgi & Ferrara, 1964) and the results indicate a late Hercynian or Lower Triassic age.

In conclusion therefore the Farkhar Slate is pre-Triassic.

C. Hinze (1964) attributed the black slates of the Farkhar valley (Farkhar Slate) to the Helmand Series which H. Hayden (1911) referred to the Carboniferous, Popol & Tromp (1954) to the Lower Devonian and E. Martina (1963) to the Carboniferous. Such conclusion are of little value when they concern similar lithotypes present at different horizons. The argument will be discussed in a later paragraph (page 186). In any case, according to Hinze (1964), the Farkhar Slate must be older than the fossiliferous sandstone formations of Permian age in Chasma Gawan (Ishkamesh) and younger than the micaschists with marble provisionally attributed by him to the Cambro-Silurian; because these latter rocks are affected by regional metamorphism whereas the Farkhar Slate might perhaps belong — according to Hinze — to the Devonian-Carboniferous interval.

Mirzod, Kolchanov & Marucharjantz (1968) also discuss this formation and compare it with the Upper Devonian — Upper Carboniferous series in the Farand chain on the left bank of the Surkhab river, and conclude that it is probably of Carboniferous age.

We have no other data than those recorded above by which to judge these results.

2.2. Shingan Conglomerate (Sf).

Type-Section. — The type-section, 100 m thick, was measured near Shingan in the Farkhar valley (69° 48′ east Long., 36° 37′ north Lat.).

The base of the section is not exposed at this point because the alluvial deposits of the Farkhar river mask the contact with the underlying Farkhar Slate.

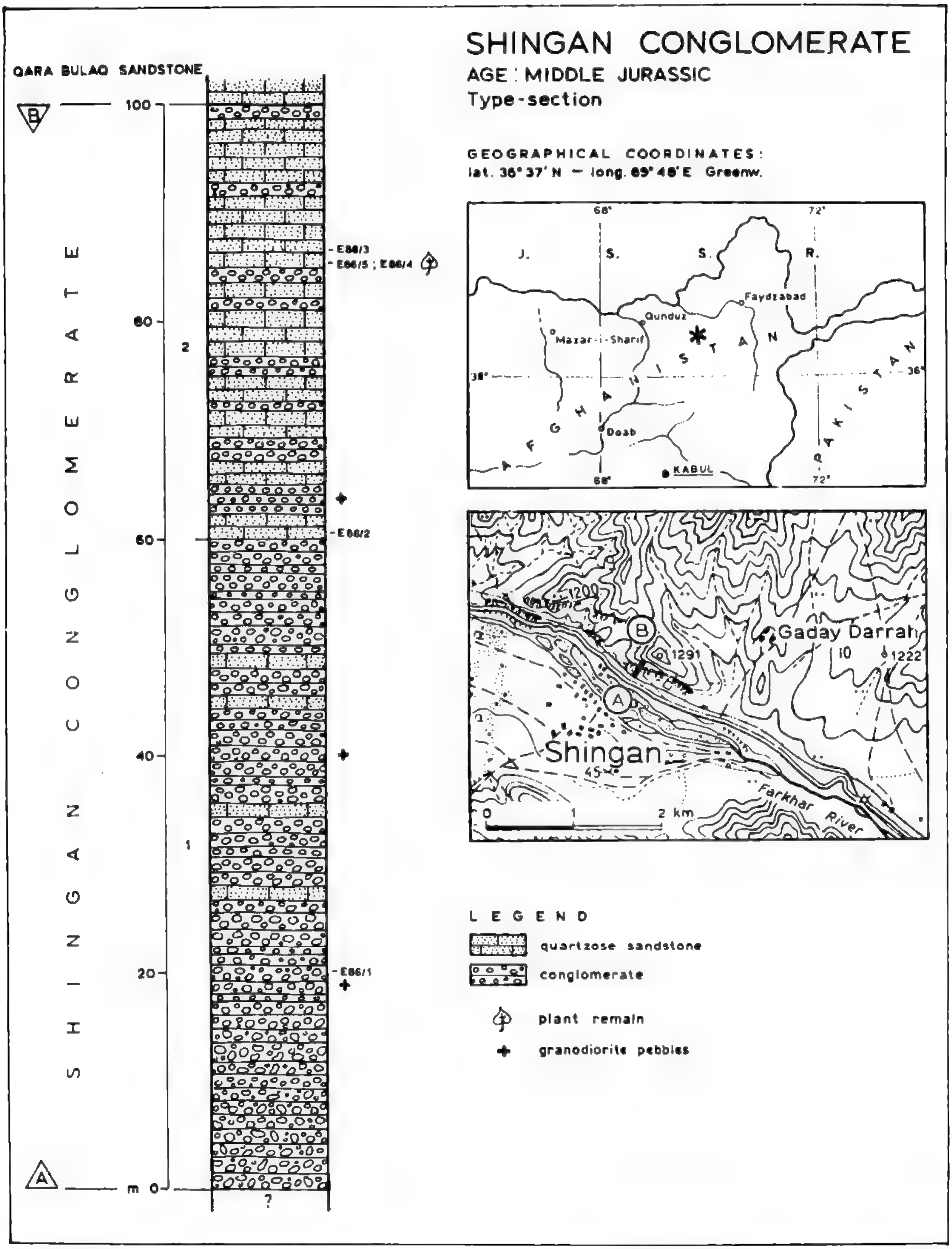

Fig. 6 - Type-section of the Shingan Conglomerate.

From the top to the base stratigraphical sequence is as follows (Fig. 6):

— Qara Bulaq Sandstone;

2) Grey and grey-green conglomerate analogous in composition to the underlying beds with intercalations of fine-grained, greenish, micaceous sandstone (61 AE-86/2), containing poorly preserved remains of fossil plants (61 AE-86/4) and small pelecypods (61 AE-86/5), 40 m;

1) Grey and grey-green conglomerate (61 AE-86/1) with rounded pebbles, some of them up to 8 cm in diameter, composed of black slate, quartz and granodiorite, regularly bedded, 60 m;

— Farkhar river alluvial deposits.

The Shinghan Conglomerate passes gradually near the top into the red sandstones of the Qara Bulaq Sandstone, which can be seen both near Shinghan and Aq Bulaq.

At the base, on the other hand, the Shingan Conglomerate rests unconformably on the Farkhar Slate, as can be seen at Gazestan where, on top of the Farkhar Slate there are 10 metres of sandstone (61 AE-81/1) and 50 metres of conglomerate with granodiorite pebbles (61 AE-81/2), which is followed by alluvial deposits and the Gazestan Formation. Also, at Idel, south of Astana Tepa and Aq Bulaq, the Shingan Conglomerate unconformably overlies the Farkhar Slate.

South of Kalafghan the Shingan Conglomerate thins out until it disappears and is replaced by the lowest beds of the Qara Bulaq Sandstone (units 1-3).

The rocks which compose the pebbles of the Shingan Conglomerate outcrop in the area between Kishem and the Farkhar valley.

Areal Distribution. — The Shingan Conglomerate outcrops most extensively along the right bank of the Farkhar river around Shingan (1) in the area studied. It is also present near Gazestan, Astana Tepa and above a rocky spur between Astana Tepa and Kalafghan.

Remarks. — The Shingan Conglomerate which was examined in its most

(1) The village is sited on the opposite bank of the river.

westerly exposure along the right bank of the Farkhar river appears to be present also on the opposite bank where, for various reasons, access was not possible.

That area, however, was the basis for a study by C. Hinze (1964) in which he described amongst other things a clastic deposit of black shales, light-grey sandstone and conglomerate with thin beds of coal which were referred to the Saighan Series of Hayden (1911).

The correlation of the formation described here with that described by Hinze, or at least a part of it, is strengthened by the presence in the Shingan Conglomerate, in the Farkhar valley, of poorly preserved remains of fossil plants (horizon 2 of the type-section).

Hinze also has attributed the conglomerate which outcrops on the Koh-i-Shagarak (1291 m) situated to the east of the village of Farkhar to this formation, on the right bank of the river. It is really an epimetamorphic quartzose conglomerate, without granodiorite pebbles which is intercalated in the Farkhar Slate and not overlying it transgressively like the Shingan Conglomerate. This lithotype is represented by unit 5 of the Farkhar Slate type-section (page 49).

Age. — On the geological maps published in 1964 and in the preliminary notes (Desio, Martina & Pasquarè 1964) the Shingan Conglomerate was attributed to the Lower Cretaceous.

As a result of a lack of secure chronological references since the plant and animal fossils collected during this study have proved indeterminable, all the arenaceous-conglomeratic deposits of the Gazestan Formation have been interpreted as clastics deposited immediately before the Albian-Cenomanian transgression, that is of Lower Cretaceous age.

Now, however, on the basis of what has been presented above, it is possible to deduce that the age of the Shingan Conglomerate must be the same as the clastic formation which outcrops in the region situated to the west of the Farkhar river, near the localities of Takatoymast, Kohna, Queshaq and Tamburak. The age of this latter formation is based on the fossil flora studied by L. Benda (1964) and referred to the Dogger. It is also possible that in the Saighan Formation in the region studied the Lias is also present, however, according to Benda this cannot be confirmed because the evidence is insufficient.

THE RELATIONSHIP BETWEEN THE SHINGAN CONGLOMERATE AND THE SAIGHAN FORMATION. — Some discussion is necessary to define the relationship between the Shingan Conglomerate and the Saighan Series of HAYDEN (1911). The first question is whether the Saighan series is a stratigraphical unit which corresponds to a formation. C. HINZE (1964) writing in German used the term *Saighan Series* on his geological map (plate 16), but he translated it into English as the *Saighan Formation*. D. WEIPPERT (1964) wrote *Saighan-Schichten*, that is Saighan beds or Saighan Series with reference to HAYDEN's nomenclature. However, it is obvious that we are dealing with a formation of clastic continental origin often containing beds and lenses of coal.

Without going into great detail, it must be asked if the term Shingan Conglomerate should be suppressed or retained as distinct from the Saighan Formation. The answer is that the two formations are not the same, since the Saighan Formation of the type-area is characterised by a predominance of fine-grained rocks in comparison with the coarse-grained ones, whereas the inverse is true in the case of the Shingan Conglomerate. Furthermore in the latter there are no tuffs or coal. There are however remains of fossil plants. Moreover, the base of the Shingan Conglomerate does not correspond to the base of the Saighan Formation; in the area surveyed the lower beds of the Saighan Formation are probably missing, as well as all the Doab Formation is missing.

Another difference between the Shingan Conglomerate and the Saighan Formation is the presence in the first of granodiorite pebbles, which according to POPOL and TROMP (1), are missing from the Saighan Formation, while they are present in the Red Grit, 70 m above the base (Ishpushta). We must, however, note that presence or absence of plutonic rocks in an area in which such rocks of different ages outcrop cannot be taken as a rule, especially when the conglomerate deposits are many kilometres apart.

In spite of these differences, it is considered probable that the Shinghan Conglomerate represents a part; perhaps it might be called a member of the Saighan Formation, well enough defined, at least in the area studied, to merit being maintained as a distinct lithostratigraphic unit for further detailed studies.

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(1) They speak about granite (1954, p. 377).

2.3. Qara Bulaq Sandstone (Qf).

TYPE-SECTION. — The type-section, 190 m thick, was measured near the small village of Qara Bulaq, west of Kishem (7° 02′ east Long., 36° 45′ north Lat. (Fig. 7).

From the top to the bottom the stratigraphical sequence is as follows:

— Mashad Limestone;

5) fine-grained, massive, not well bedded reddish quartz-sandstone, 20 m;

4) thick beds (61 AE-49/5) of conglomerate whose components are pebbles of white and reddish quartz and black slate up to 5 cm, embedded in a reddish quartzitic-arenaceous cement, 20 m;

3) fine-grained, massive reddish sandstone with thin intercalations of fine-grained conglomerate consisting of pebbles of white quartz embedded in a reddish quartzitic-arenaceous cement, 20 m;

2) green and red arenaceous shale (61 AE-49/4) with intercalations, mainly in the upper part, of green and red quartzitic sandstone in beds from 10 to 20 cm thick, 100 m;

1) poorly cemented light-green quartz-sandstone (61 AE-49/3) and fine-grained, green quartzitic-arenaceous breccia with embedded small pebbles of white, black and pink quartz, 30 m;

— Farkhar Slate (61 AE-49/1, 49/2).

In the Qara Bulaq and Kishem regions the Qara Bulaq Sandstone is unconformably overlying (angular unconformity) the Farkhar Slate. To the south-west of Aq Bulaq as far as the Farkhar valley, this formation overlies a 50 m thick bed of Shingan Conglomerate.

In the Qara Bulaq and Kishem regions the Qara Bulaq Sandstone underlies the Mashad Limestone; on the contrary, in the area between Qara Bulaq and Aq Bulaq, its upper part passes into the Mohammad Aba Sandstone and, locally, the Gazestan Formation as it is visible on the rock-wall overlooking to the north-east the cross-road to Farkhar along the carriage road between Taluqan and Kishem.

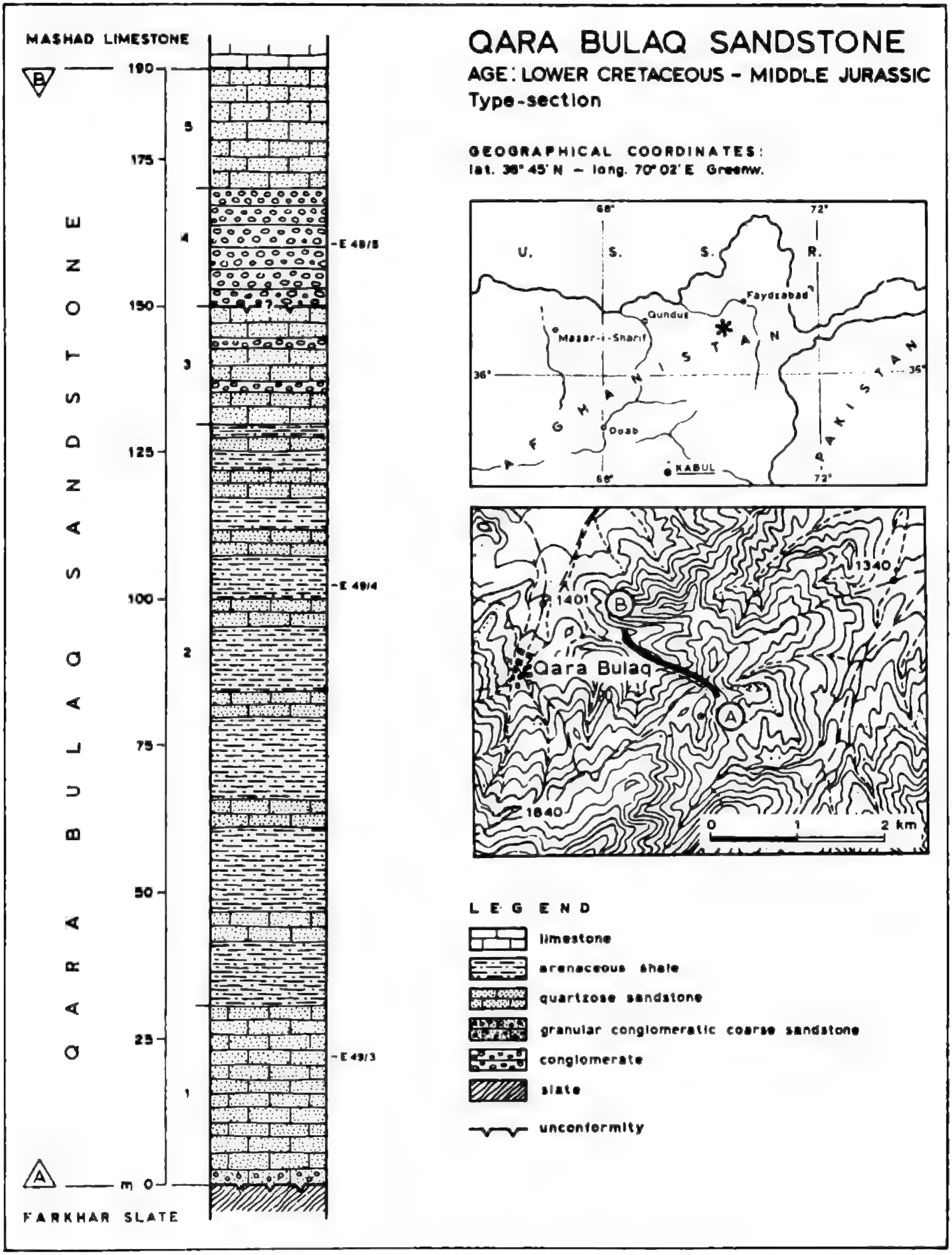

Fig. 7 - Type-section of the Qara Bulaq Sandstone.

Other Sections. — In order to illustrate better these other sections, it is useful to describe here the most representative part of this formation surveyed, downhill from the mountain top marked 1892 m, along the rocky slope descending to the south-east, towards Qara Tut and overlooking, to the west, Baba Darwes. From the top to the bottom the stratigraphical sequence is as follows [1].

— Gazestan Formation;

6) red sandstones and argillites (61 AD-48/8), 49 m;

5) grey-green, fine-grained quartzitic sandstone (61 AD-48/6), 10 m;

4) breccia consisting of white quartz and scarce black argillite fragments passing into conglomerate and whitish quartzitic sandstone (61 AD-48/5), 2 m;

3) light-grey, fine-grained quartzitic sandstone with plant remains and impressions (61 AD-48/4), 3 m;

2) whitish and greenish, quartzitic siltstone with clayey cement (61 AD-48/3), 6 m;

1) grey-greenish quartzitic sandstone (61 AD-48/1, -48/2), approximately 150 m;

— Farkhar Slate.

Correlations with the surrounding formations. — At this locality the Qara Bulaq Sandstone overlies the Farkhar Slate without the interposition of the Shingan Conglomerate. We must point out that in horizon 3 are present plant remains and impressions which were also observed in the Shingan area, where remains of plants are present in horizon 2 of the Shingan Conglomerate. We can therefore assume that a lateral facies variation of the Shingan Conglomerate into the Qara Bulaq Sandstone occurs proceeding from Shingan towards Kishem, that is from south-west to the north-east. Finally, between Astana Tepa and the Farkhar valley, the Qara Bulaq Sandstone underlies the Gazestan Formation as it is well visible on the

(1) A detailed description of the microfacies found in the samples collected here is shown in the Micropalaeontological Appendix 2.

rock-wall overlooking to the north-west the cross-road to Farkhar along the road between Taluqan and Kishem.

From the point of view of stratigraphic correlations, the two cross-sections described above lend themselves to be interpreted in three different ways. The first interpretation is that the beds of the Qara Tut section could be equivalent to those of the type-section although the former beds, with the exclusion of the upper horizon, do not have the characteristic red colour (horizon 6). In this case the Shingan Conglomerate would be absent: we could assume that in the Qara Tut area it was removed by erosion.

On the other hand the Qara Tut section could be inclusive not only of the type-section beds, but also of the Shingan Conglomerate.

Both interpretations are supported by the fact that fossil plant remains are present in horizon 3 of the Qara Tut section; we believe that the second interpretation is the most satisfactory as the red colour of the rocks is not present in the whole type-series and, especially in the lower horizons, is partly replaced by green and grey colours which are most prominent in the Qara Tut section. Such close relationships of lithological composition can have a considerable meaning.

Areal Distribution. — The Qara Bulaq Sandstone outcrops in the area between Kishem and the Farkhar valley; according to our interpretation it does not extend further west.

Age. — Only poorly preserved fossils are present in the Qara Bulaq Sandstone and no determinations were possible; we used as markers the fossil plant remains.

As previously mentioned, proceeding from Kishem towards the Farkhar valley, the lower part of the Qara Bulaq Sandstone grades into the Shingan Conglomerate. Therefore the lower part of this formation has the same age as the Shingan Conglomerate, that is Middle Jurassic (Saighan Formation). The indeterminate plant remains present in horizon 3 of the Qara Tut section could confirm their correlated age.

Consequently, the upper part of the Qara Bulaq Sandstone, where the reddish colour of the arenaceous deposits begins to prevail, should correlate with the detrital deposits of Lower Cretaceous age (Red Grit facies). It is difficult, using the data available, to define, in the investigated area, the chronostratigraphic limit between the Middle Jurassic and the Lower Cre-

taceous; perhaps only part of the Upper Jurassic clastic sediments are present between the two. As a result of this fact the lower and upper parts of Qara Bulaq Sandstone were not differentiated on the geological map enclosed in this report; lacking precise chronological dating, they were assigned to the Lower Cretaceous together with the Shingan Conglomerate because, at that time, the Jurassic fossil floras on the left bank of the Farkhar river were not known (HINZE and BENDA, 1964).

However it is probable that the boundary between the Middle and perhaps Upper Jurassic and the Lower Cretaceous, difficult to define as both are similar arenaceous deposits in contact with each other, coincides with the locally outcropping reddish conglomerate horizons (horizon 4 of the Qara Tut section; horizons 3 and 4 of the Qara Bulaq section).

Finally, the lower part of the Qara Bulaq Sandstone which represents a lateral facies variation of the Shingan Conglomerate, grading from arenaceous into conglomeratic, and containing, as in the latter one, fossil plant remains, is ascribed to the continental facies of the Middle Jurassic; this Middle Jurassic facies can be correlated with the upper part of the Saighan Formation also, if between them there are remarkable lithologic differences which could allow us to differentiate them. The upper part of the Qara Bulaq Sandstone, beginning probably from horizon 4 of the Qara Tut section and from horizons 3 and 4 of the type-section, represents, on the contrary, the clastic sediments (Red Grit facies) of the Lower Cretaceous beds underlying the deposits of the Albian-Cenomanian transgression (see Gazestan Formation).

THE RELATIONSHIPS BETWEEN THE QARA BULAQ SANDSTONE AND THE « RED GRIT ». — « Red Grit » is a widely used stratigraphical term in northern Afghanistan; it was introduced in 1886 by C. L. GRIESBACH and then also used by H. H. HAYDEN (1911) and other authors (POPOL & TROMP, 1954; DESIO, 1961). It does not seem that this term was interpreted in the same way by the various authors either because the correlations made were very far apart or because the red colour is not confined to the same stratigraphic horizon.

In order to establish its characteritics we shall refer to a type-series described by the author who first used this term. GRIESBACH (1886, page 56) uses for the first time the term « Red Grit » in connexion with the Band-i-Baba, in northwestern Afghanistan, where the « Red Grit group » consists

of three arenaceous-conglomeratic horizons derived from volcanic rocks. Only the lower horizon shows the characteristic red colour; the upper one is blue-green coloured and the middle one is dark green or red. The « Red Grit group », which has been assigned an Upper Jurassic and Neocomian age in the Band-i-Turkestan region, grades upwards into clastic deposits ascribed to the Lower Cretaceous, while further to the east, in the Doab region, it is apparently discordantly overlain by the Cretaceous limestone. Also in the Band-i-Turkestan region the « Red Grit group » presents, according to GRIESBACH, the same clastic facies with volcanic material, also as tuffs, and contains some poor remains of plants, for the most part only impressions of straight stalks and carbonised matter.

In this region, below the « Red Grit group », there are grey micaceous sandstone and thick beds of greyish-blue grits with intercalations of friable black shales which evidently represents the Saighan Formation.

HAYDEN (1911) with reference to the Doab region (Ishpushta) characterised the red sequence by the name of « Red Grit Series » pointing out that « the plant bearing series (Saighan Formation) grades up, through pebble-beds, into a great thickness if intensively red rocks, consisting chiefly of grit, pebbly sandstone and conglomerate and probably belonging to the Cretaceous ».

As regards the upper part of the « Red Grit » HAYDEN writes (1911, page 36): « The uppermost beds of the Red Grit series are a red limestone overlain by a red pisolitic rock very like "low level" laterite. This is overlain by a conglomerate followed by sandstone and gypsum, overlain in turn by limestone. There appears to be a slight discordance at the base of the conglomerate, which, together with the sandstone and gypsum, seems to belong to the overlying limestone. Often, however, these beds are absent and the limestone, which is usually a flaggy rock made up of comminuted fragments of shells, lies unconformably on everything below. There is thus, at the base of the limestone, a well marked overlap, representing the great Cretaceous transgression which affected such a wide area in Central Asia and which is usually attributed to the Cenomanian period ».

POPOL and TROMP (1954, page 378) attributed to the « Red Grit series » a thickness varying from 80 to 320 m and consisting of « greenish clay, in places rich in gypsum beds, alternating with reddish sandstone. Sandstone usually dominates, except near Ishpushta, where a few conglomerates inter-

calations seem to occur in this section; near the top, beds plant fragments and thin coal seams have been found ».

A stratigraphic section in the Red Grit was surveyed uphill from Barfaq by A. Desio (1961, pages 28-29) and another one by E. Martina (page 114). These investigations show that at this locality its thickness is much less (12 m) and that its composition is arenaceous-conglomeratic. The « Red Grit » is underlain by the Saighan Formation and overlain by more than two metres of sandy clays and yellow and green conglomerates which are in turn overlain by the fossiliferous calcareous series of the Upper Cretaceous.

We must now mention that the « Red Grit » is also present (Desio, Cita & Premoli Silva, 1965) in the stratigraphic section in the neighbourhood of Karkhar, located between the Doab region and the Badakhshan. Here a succession of red beds more than 200 m thick, having a prevailing arenaceous-conglomeratic composition and overlying the upper member of the Karkar Formation, have been ascribed to the « Red Grit ». This latter one was deposited in a lagoonal environment and overlies typical marine sediments while the « Red Grit » is considered to be deltaic environment and, in part, probably, of continental origin; unconformably overlying other sediments of Lower Cretaceous age. The « Red Grit » in turn, is overlain by a group of clastic beds which we consider to correspond to the « Green Beds » of Griesbach, transgressive onto the « Red Grit » and of Cenomanian—Turonian age. In this area the red colour of the rocks is not limited to the « Red Grit » but is also present in other horizons and in the Karkar Formation.

G. Gabert (1964) (1), in a report concerning the same area of Karkar, includes also in the « Red Grit » our upper Karkar Formation. Taking into consideration its lagoonal facies and the unconformity, we prefer to link it with the underlying neritic beds rather than with the overlying deltaic-continental ones; we interpret it as the last deposit of the marine cycle.

We can conclude that the « Red Grit » has everywhere a clastic lithofacies and prevalent red colour. In the investigated area the lower limit is at the top of the Saighan Formation whereas the upper limit varies from place to place and there is disagreement among the authors about its stra-

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(1) This report, wich is dated 20th November 1964, was released at least in Italy, only in June 1966 when our publication on the Karkar Formation was seven months old.

tigraphic position. Regarding the age, with the exception of GRIESBACH, all the authors think it is Lower Cretaceous.

D. WEIPPERT discussed at lenght the « Red Grit » in a report (1968) describing the Cretaceous sediments of the north Hindu Kush foreland. The author founded his interpretations on data reported by previous authors, especially on data collected by his German colleagues, omitting all the Italian reports (even those in English) which deal with this problem (DESIO 1960; ROSSI RONCHETTI & FANTINI SESTINI 1961; DESIO, MARTINA & PASQUARÈ 1964a and 1964b) and listed also in the previously published accurate bibliographic revision by M. KAEVER (1967 b). However, WEIPPERT considers the « Red Grit » as a facies and therefore finds this type deposit repeated also in higher horizons of Lower Cretaceous age. Red clastic deposits of the « Red Grit » type are thus also reported in the Pull-i-Khumri Formation as intercalations in the beds of Cenomanian and Maastrichtian age.

It is doubtful whether there is any need to modify the primary stratigraphic meaning given by GRIESBACH to the term « Red Grit » which was changed by WEIPPERT from a lithostratigraphic horizon term into a facies term. The term « Red Grit » could have been retained in its primary meaning if a different nomenclature had been used for the « red clastic facies » present in northern Afghanistan. The term « Red Grit » is applicable to a group or a formation of deltaic or continental type and thus subject, due to these characteristics, to considerable variations not only in composition but also in its upper and lower boundaries. This latter facies is also present in horizons different from those described by WEIPPERT in the Pamir and Tadzikhistan.

Bearing in mind what has been said previously, we think it is advisable to retain Qara Bulaq Sandstone, which has well defined upper and lower boundaries, as a separate local formation. This formation represents the « Red Grit » only in part, including perhaps in its lower section, a part of the Saighan Formation (to the east) and not reaching the uppermost parts of the northern Afghanistan stratigraphical series, as the original « Red Grit » does.

REMARKS. — In reconstructing the distribution of the various Cretaceous facies, WEIPPERT emphasized the marginal position of the « Red Grit facies »

in the north Afghan basin (1968, fig. 4), its gradual areal reduction and the substitution by the calcareous facies ranging in age from the Lower Cretaceous to Palaeocene.

Deposits with red clastic facies, as the « Red Grit » of Lower Cretaceous age, are however present also to the north of the Amu Darya, in the Tadzhikistan part of the Upper Amu Darya Depression (S. J. JL'IN et al., 1947). Here too they are represented by a « red-coloured deltaic facies » which to the west gradually changes into thin marine deposits. According to JL'IN the sinking of the region between the montainous areas of Pamir and Hissar—Alai, which included the South Tadzhik Depression and the south-western spurs of the Hissar range, caused the development of a large delta in which a thick series of red deltaic sediments are present. The composition of the sediments indicates that most of them came from an emergent region to the north-east: the deposit also reaches its maximum thickness in that direction (800-900 m). Other rivers descended from the northern and south-eastern parts of the Alai range.

Similar phenomena also occurred in the southern part of the Upper Amu Darya Depression where the region investigated by us is located.

2.4. Gazestan Formation (Gf).

TYPE-SECTION. — The type-section was surveyed in front of the village of Gazestan, in the Shor valley (69° 47′ east Long., 36° 41′ north Lat.). Its thickness is 175 m (Fig. 8).

From the top to the bottom the stratigraphical sequence is as follows:

— Baba Darwes Formation;

7) reddish conglomerate and sandstone, crystalline white gypsum and grey and white zoned microcrystalline gypsum, 30 m;

6) grey-brown, well bedded massive limestone lighter coloured when altered, 10 m;

5) white crystalline gypsum, 5 m;

4) reddish sandstone and marl with some lenticular gypsum, 40 m;

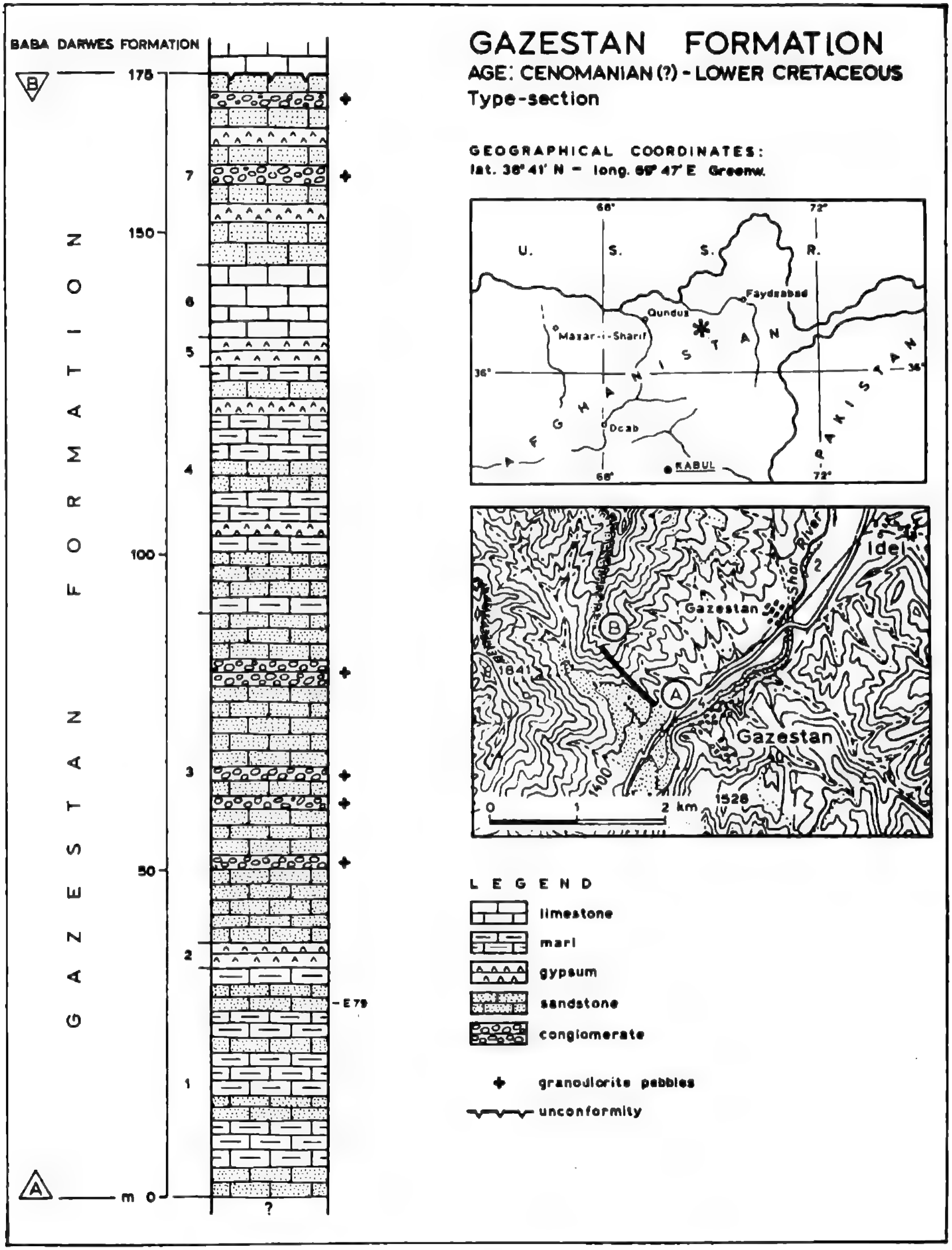

Fig. 8 - Type-section of the Gazestan Formation.

3) conglomerate with quartz-pebbles, black slate, granodiorite and grey-green, coarse quartzitic sandstone, 50 m;

2) white crystalline gypsum and white and grey zoned microcrystalline gypsum, 5 m;

1) red, green and grey marl and sandstone (61 AE-79), 35 m;

— alluvial deposits of the Darya-i-Shor.

The Gazestan Formation is overlain, perhaps unconformably, by the Baba Darwes Formation and overlies the Qara Bulaq Sandstone (Fig. 8).

In the Astana Tepa area the Gazestan Formation increase in thickness until it reaches 200-300 m due to the considerable development of gypsum and rock-salt lagoonal deposits (Plate I, fig. 2). Rock salt is being mined out of a lens just above the village of Astana Tepa.

The rock-salt, reddish or greyish or greenish, appears rather impure due to the presence of clay (61 AD-53). Its visible thickness averages 12 m and the beds are poorly defined and sub-horizontal.

The rock-salt lens is completely envelopped in reddish, impure and earthy ochraceous clay. Above the rock-salt there are irregular beds of gypsum. At approximately 100 m above the mine we found blocks of brown limestone containing Cretaceous fossils. About the position of the evaporitic body among the other formations we can suppose that it was subject to a small lifting displacement as a diapiric effect.

The Kalafghan or, more precisely, the Astana rock-salt mine is located one and half kilometres to the north of Archa Kotal village. Mining is carried out in trenches and on a small scale (Plate I, fig. 1). Small furrows 15 cm deep are cut by hand with the help of small pickaxes at intervals of 30 and 60 cm respectively at the bottom of the trench in order to separate blocks of rock-salt measuring $15 \times 30 \times 60$ cm and and weighing about 22-25 kg. The blocks are hand-carried out of the trench where they are weighed and loaded on donkeys and taken to Archa Kotal where they are weighed and loaded on trucks.

Salt-water springs are present in the area, both near Astana Tepa and further to the north, on the northern slope of the Koh-i-Namak (rock-salt mountain).

Other Sections. — The Gazestan Formation is exposed in the rock-wall which overlooks from the north-west the cross-road to Farkhar along the

road between Taluqan and Kishem. The following stratigraphic sequence was found (1):

— Baba Darwes Formation;

9) red chalky marl (61 AE-87/10) and withe crystalline gypsum with some interbedded marly limestone, 70 m;

8) crystalline gypsum, white and grey microcrystalline gypsum and red chalky marl alternating every 2-3 m; at 5 m intervals there are 1 m thick intercalations of a grey foraminiferal limestone (oosparite) (61 AE-87/9); total thickness 60 m;

7) white crystalline gypsum (61 AE-87/8), 2 m;

6) red chalky marl, 2 m;

5) grey limestone (micrite), 2 m;

4) red, chalky arenaceous marl (61 AE-87/7), 5 m;

3) beds, 10-30 cm thick, of grey limestone (micrite) with oolites, small ostracodes and rare Miliolidae (61 AE-87/6), 8 m;

2) grey limestone (intramicrite) with molluscan fragments and rare agglutinating foraminifera (51 AE-87/5a), reddish limestone (oosparite) and beds, 50 cm thick, of grey limestone (intramicrite and biomicrite) (61 AE-87/5b) with molluscan fragments, probable Ostreae, echinoid spines and plates and pieces of bryozoa, 3 m;

1) grey-light, brown, massive dolomitised calcarenite (sandy microsparite) in sheared beds 10-30 cm thick with scarce agglutinating foraminifera (61 AE-87/4), 4 m;

— Qara Bulaq Sandstone.

At this locality the Gazestan Formation has a total thickness of 156 m.

Further north-east, just west of Archa Kotal, the Gazestan Formation shows the same sequence. In particular, it can be mentioned that the same oo-biosparite with molluscan fragments (probable Ostreae), echinodermata, corals, and rare Miliolidae (61 AE-77/1) is also present in horizon 2 (61 AE-87/5b) of the Farkhar section.

To the north-west of Archa Kotal village a small coal lens outcrops (61

(1) A detailed description of the microfacies is enclosed in the Micropaleontological Appendix 1.

AD-49 bis) and is interposed between an underlying bed of grey-green conglomerate and an overlying bed of green marl (61 AD-49 bis) (Fig. 9). The coal is very impure, very friable and occurs together with brown, earthy material. No determinable fossils were found.

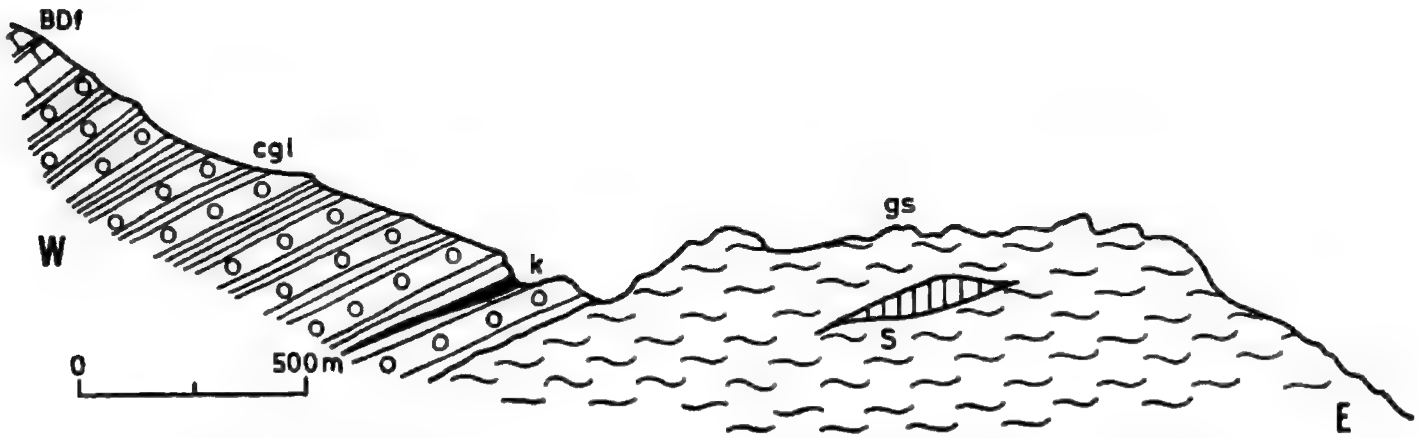

Fig. 9 - Stratigraphical sequence of the Archa Kotal area after a sketch-map of Desio's field book. (BDf = Baba Darves Formation, cgl = conglomerate with clay and sandstone, gs = gypsum, S = rock-salt.

The three lithotypes previously mentioned belong to a sequence consisting of green and red conglomerates interbedded with red, purple, green and grey earthy clays and sandstone. This sequences overlies a gypsum deposit consisting of white, veined, crystalline gypsum and red earthy clays with some rock-salt lenses. The beds dip at 25°-30° to the south-west.

In a small neighbouring valley, not far to the east, there is a small outcrop of white sub-crystalline limestone (intra-biosparite) not well bedded, with Miliolidae and Rotaliidae (61 AD-50) at the base of the above mentioned conglomerate; this conglomerate overlies the limestone and an angular unconformity is present between the two.

Above this conglomeratic sequence there are beds of limestone which are part of the Baba Darwes Formation.

The arenaceous-marly-conglomeratic sequence which here represents the upper part of the Gazestan Formation, also present at Gazestan in horizon 7 of the type-section, can be correlated with the upper part of the Mohammad Aba Sandstone: in both cases it underlies the fossiliferous limestones of the Baba Darwes Formation. It appears likely that the previously mentioned conglomerates represent the first deposits of the Baba Darwes trangressive Formation (Upper Cretaceous).

In the section measured on the rock-slope descending from the south-east towards Qara Tut, from the mountain top marked 1892 m and located to the west of Baba Darwes, the following stratigraphic sequence, more than 160 m thick, can be observed from top to bottom:

— Baba Darwes Formation:

11) green and yellowish, medium-grained sandstone (61 AD-48/18) interbedded with greyish fossiliferous limestones (sandy biosparite) containing mollusca, echinodermata, bryozoa, foraminifera, *Saccocoma* (61 AD-148/18a, 18b), 30 m;

10) green and yellowish, thick bedded, massive sandstone, 5 m;

9) green sandstone alternating with red marly sandstone, predominant in the upper part, 8 m;

8) conglomerate with 2-3 cm pebbles consisting of quartz and black slate green sandstone, 1,50 m;

7) green, red and yellowish sandstone, beds 30-50 cm thick, alternating with red marly sandstone, 40 m;

6) conglomerate with 2-3 cm pebbles consisting of black slate, 4 m;

5) green sandstone, more than 40 m;

— fault

4) green sandstone, more than 40 m;

3) grey, massive limestone (micrite) crossed by numerous calcite veins (61 AD-48/11) (Mashad Limestone), 4 m;

2) white, veined, crystalline gypsum, 6 m;

1) reddish-green at the base, fine-grained sandstone (61 AD-48/9), 20 m;

— Qara Bulaq Sandstone.

The Qara Tut section, occurring between the Baba Darwes Formation and the Qara Bulaq Sandstone, was surveyed at the point where the Gazestan Formation, represented by horizons 1, 2, 6, 7, 8, 11, grades laterally into the Mohammad Aba Sandstone which comprises horizons 4, 5, 9, 10. In fact, some horizons characteristic of both formations are alternating here.

Further more, the western end of the Mashad Limestone appears in horizon 3.

Areal Distribution. — In the region studied the Gazestan Formation outcrops in the area between the Qara Tut and the Farkhar valleys and apparently it continues to the south-west towards the Namak Ab valley. Conversely, to the east and south-east of Astana Tepa and Aq Bulaq, where it reaches its maximum thickness, it is replaced by the Mohammad Aba Sandstone.

Age. — The age of the Gazestan Formation is still doubtful. We can, however, say that it constantly underlies the Baba Darwes Formation the lowest sediments of which date from the Albian—Cenomanian. Much more doubtful are the data concerning the lower part of this formation. We only know that it overlies the Qara Bulaq Sandstone the age of which, in turn, is not precisely known. Considering, however, that the Gazestan Formation includes evaporitic deposits and it is at the base of a sequence of marine calcareous sediments (Baba Darwes Formation) beginning in the Albian-Cenomian, it is reasonable to assume that it represents the first deposits of the Albian-Cenomian trangression and therefore has presumably an Albian age.

Remarks. — The Astana Tepa lagoonal deposits containing gypsum and rock-salt, which were mentioned by Brückl in 1935 who assigned them to the Tertiary, are then much older. Twenty kilometres south-west of Astana Tepa, in the Namak Ab (salt water) valley, a thick rock-salt outcrop is visible which appears to be located on the southern extension of the Gazestan Formation. We were not able to visit that region, but H. de Cizancourt & Vautrin (1937) had already said that the rock-salt is, at this location, directly overlying the « Red Grit » and assigned it to the Cretaceous. Popol and Tromp, on the contrary, suggested that the same outcrop could be Miocene.

C. Hinze (1964), in his report concerning the Namak Ab region, said that the gypsum and the rock-salt of Taqcha Khana and Chal (15 and 22 km south-east of Taluqan respectively) underlie the limestones and marls of the Upper Cretaceous (representing our Baba Darwes Formation or the Pull-i-Khumri Formation) and overlie the Saighan Series. The author has, there-

fore, assigned the evaporitic deposits to the « Lower Red Grit » (Lower Cretaceous). It is believed that the evaporitic deposits of the Namak Ab region are of the same age as the Gazestan Formation deposits of Astana Tepa—Kalafgan and Namak Ab) and mark the beginning of the Albian—Cenomanian transgression. They can be correlated with the so called « Green Beds ». From the palaeogeographical point of view, the depositional environment of the lagoonal deposits of Astana Tepa, which were accumulated above the clastic sediments belonging to the upper part of the Qara Bulaq Sandstone, were deposited in a small basin-like trough which pre-existed to the crystalline basement. The basin had already been partly filled by the continental deposits belonging to the Shingan Conglomerate and by the lower part of the Qara Bulaq Sandstone, dated as Middle Jurassic. In the Astana Tepa area the evaporitic deposits of the Gazestan Formation are in fact located in a saddle-shaped hollow present in the Jalmish Tonalite and in the overlying metamorphic deposits belonging to the Farkhar Slate. These latter deposits outcrop between the tonalitic body of Khan Asman—Kashan and the small tonalitic dome encircled by the Farkhar Slate, at a location 3 km east of Idel. This evaporitic basin was closed to the east; it is, in fact, in this direction that the evaporites of the Gazestan Formation grade laterally into deposits of different facies but of the same age (Mashad Limestone and, for the most part, Mohammad Aba Sandstone). Then the Gazestan Formation, the lagoonal deposits of which had infilled the basin, was overlain by limestones of the Baba Darwes Formation belonging, for the most part, to the marine Upper Cretaceous.

2.5. **Mashad Limestone** (Ml).

Type-Section. — The type-section (Fig. 10) was measured between Qara Bulaq and Kishem (70° 01′ east Long., 36° 46′ north Lat.) where its maximum thickness is about 80 m. The section comprises grey limestone in beds 10 cm to 30 cm thick, which weather yellowish-grey.

The Mashad Limestone, which outcrops only between Qara Bulaq and Kishem, overlies the sandstones of the Qara Bulaq Formation and underlies the green or rarely, reddish sandstones of the Mohammad Aba Formation.

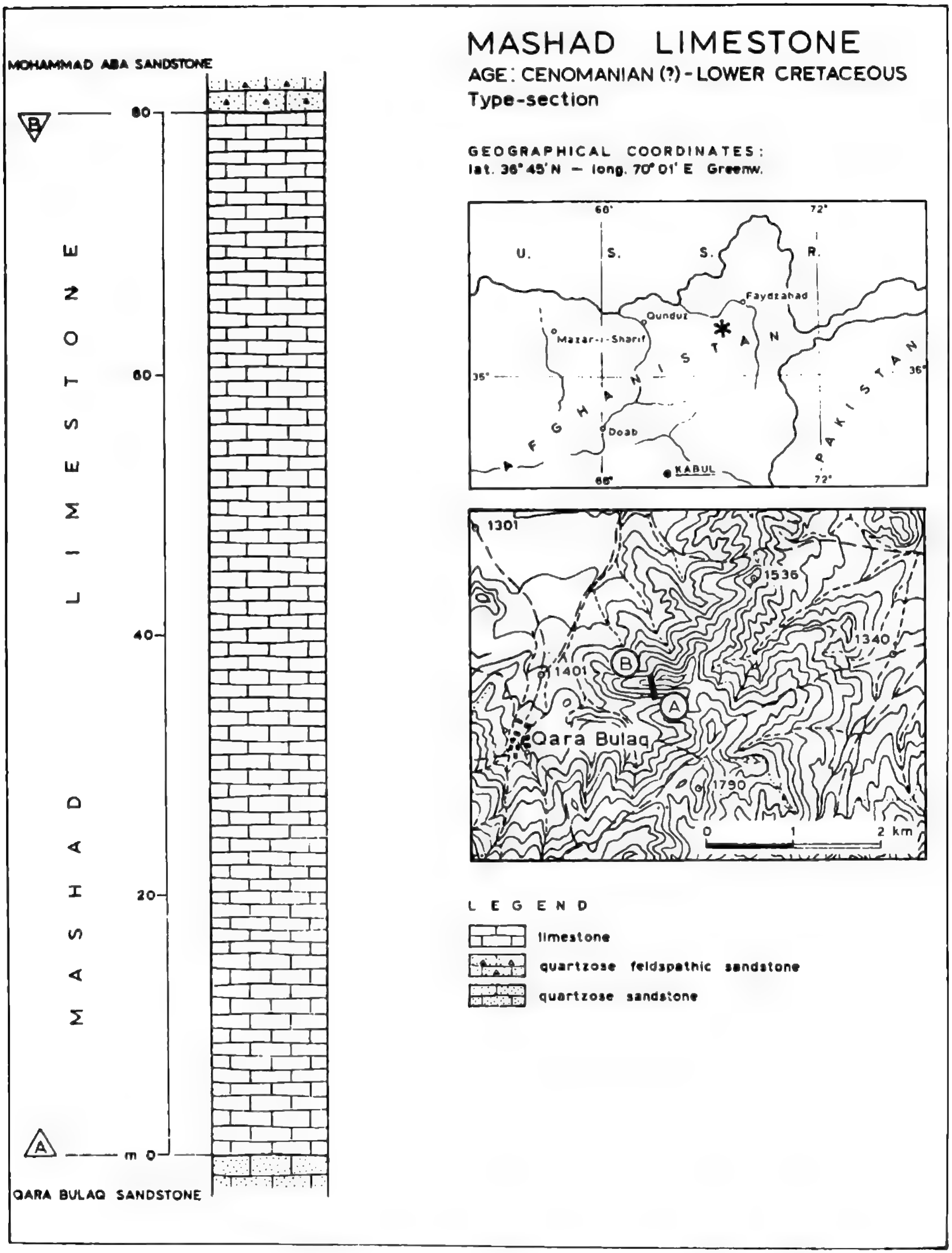

Fig. 10 - Type-section of the Mashad Limestone.

Areal Distribution. — The Mashad Limestone thins and wedges out laterally (to the west) into the sandstones and gypsum of the Mohammad Aba Sandstone and the Gazestan Formation, which in the area between Kalafghan and Qara Bulaq replace it laterally as is seen in the Gazestan Formation section mapped near Qara Tut (see page 69). In this section, the Mashad Limestone or more specifically its western end, is represented by 4 m of compact grey limestone (micrite), crossed by numerous crystalline calcite veins (horizon 3, sample 61 AD-48/11).

Towards the north-east, however, beyond the Mashad valley, the Mashad Limestone disappears underneath alluvial deposits together with all the other Cretaceous strata.

Age. — The Mashad Limestone is probably Cenomanian (?) — Lower Cretaceous (lower part) because it overlies the sandstones of the upper part of the Qara Bulaq Sandstone of Lower Cretaceous age, and also because it represents a lateral facies variation of the lower part of the Gazestan Formation which is of the same age.

2.6. Mohammad Aba Sandstone (Ms).

Type-Section. — The type-section is situated between Qara Bulaq and Mohammad Aba (7° 02′ 24″ east Long., 36° 47′ north Lat.) (Fig. 11). It is 170 m thich and the lithostratigraphical sequence is as follows (Table II, fig. 1):

— Baba Darwes Formation;

2) reddish flaggy limestone (61 AE-49/6), 20 m;

1) dark-green, compact, fine-grained quartz-feldspathic sandstone (61 AE-49 /7), 150 m;

— Mashad Limestone.

Areal Distribution. — The Mohammad Aba Sandstone outcrops only in the area between the village of Mohammad Aba, Chenar-i-Gunjeshkhan, Baba Darwes, Qara Bulaq, and Mashad. Towards the east in the zone of Kishem, the Mohammad Aba Sandstone disappears under the Quaternary allu-

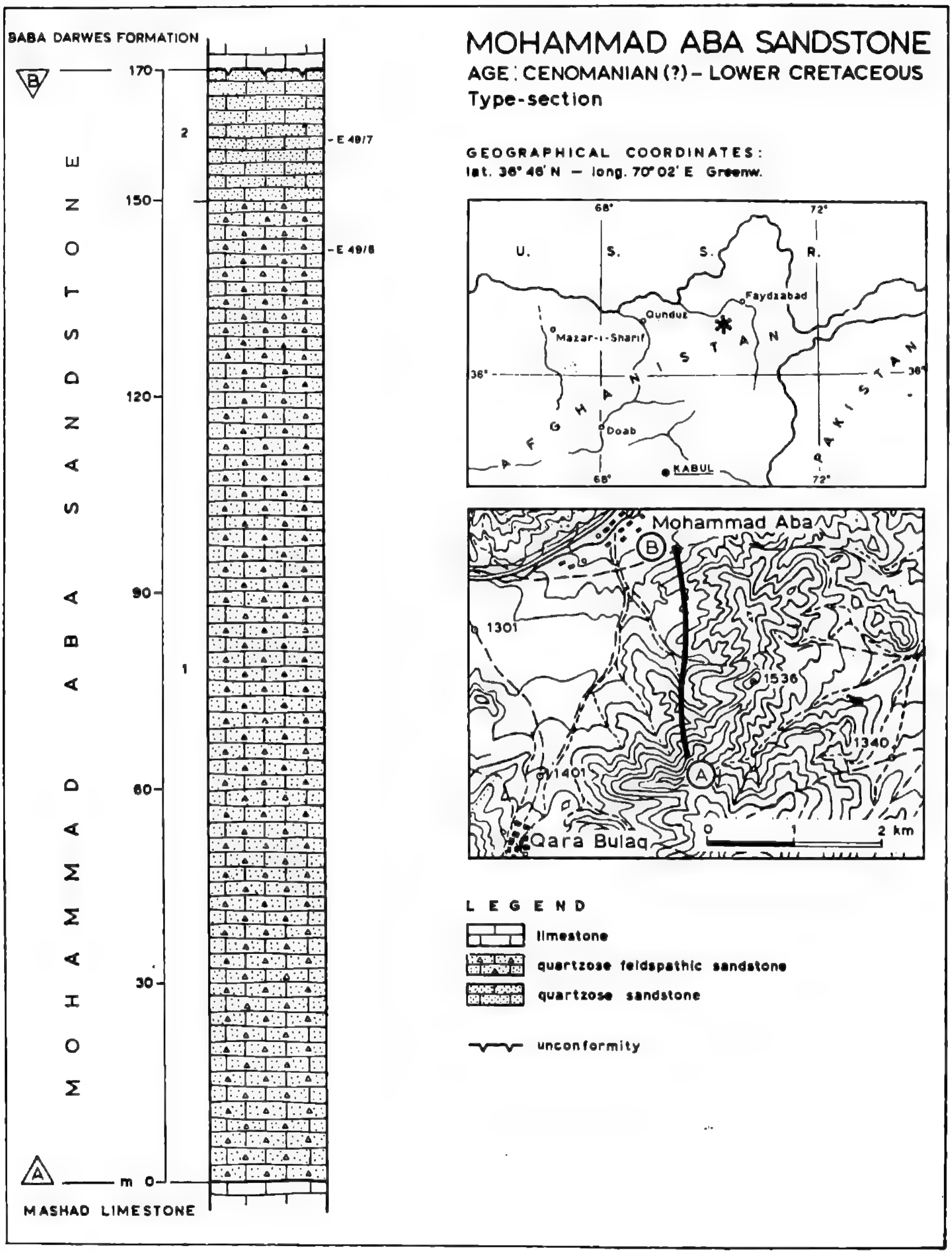

Fig. 11 - Type-section of the Mohammad Aba Sandstone.

vial cover, and towards the west and south-west the thickness decreases and it seems to grade laterally into the Gazestan Formation. In fact, as can be seen in the section of the Gazestan Formation at Qara Tut (see page 33) the horizons 4, 5, 6, 7, 8, 9, 10, 11 (located above the Mashad Limestone and below the Baba Darwes Formation) represent both the Mohammad Aba Sandstone (horizons 4, 5, 9 and 10) and the Gazestan Formation (horizons 6, 7, 8, 11).

As indicated on page 53, the Mohammad Aba Sandstone has been correlated with the arenaceous-conglomeratic lenses of Archa Kotal and Gazestan (Archa Kotal Member) which lie between the Gazestan Formation and the Baba Darwes Formation.

AGE. — The Mohammad Aba Sandstone is of Cenomanian (?)—Lower Cretaceous age, since it is found immediately underlying the Baba Darwes Formation (which starts with calcareous fossiliferous deposits of Albian-Cenomanian age in the Mohammad Aba area) and overlying the Mashad Limestone of Cenomanian (?)—Lower Cretaceous age. Moreover, the Cenomanian — Lower Cretaceous age of the Mohammad Aba Sandstone is confirmed by the correlation between horizon 11 in the Qara Tut section and horizon 2 in the Farkhar section of the heteropic Gazestan Formation, also probably Cenomanian (?) — Lower Cretaceous in age.

In conclusion, the Gazestan Formation (evaporites), the Mashad Limestone and the Mohammad Aba Sandstone, appear to represent the Albian-Cenomanian deposits of central and northern Afghanistan which are represented by the so-called « Green beds » (HAYDEN, POPOL and TROMP).

2.7. Baba Darwes Formation (BDf).

TYPE-SECTION. — The section where this formation is best exposed in the territory studied is to be found on the mountain which dominates the village of Baba Darwes on the west and on the south the pass of Chenar-i-Gunjeshkhan (Plate II, fig. 2), which is marked on the map by the trig point 1891,7 m (Fig. 12). The geographical coordinates are 69° 68′ east Long., 36° 46′ north Lat. It is a mountain ridge elongated east-west and cut through by a gorge near Baba Darwes. The strata which form the

mountain dip in a northerly direction between 35° and 45°, thus on the northern side of the mountain they dip with the slope of the mountain, and on the southern side they dip into the slope and are truncated just below the summit by a rocky wall.

Unfortunately it was not easy to measure a stratigraphic sequence with little time at our disposal because the areas corresponding to the argillaceous and marly beds are frequently covered with detritus. For this reason only the tops of the calcareous beds are seen. Moreover, a series of subvertical faults divides the hills to the south of the crest into several blocks which have probably produced at the surface a repetition of beds of the same age. This fact has emerged also as a result of the sample study which at first suggested the idea that there was confusion in the sample numbering. For the reasons mentioned above the thickness of certain beds are lacking or only approximate. On the other hand the total thickness of the stratigraphic section is considered to be reliable.

From the point of view of the lithological composition, the Baba Darwes Formation is composed of beds of compact limestone, generally grey-brown, maroon and red, alternating with beds of mudstone and sandy marls, which do not appear in the series indicated below, because they are only rarely exposed. The highest beds, of reddish colour, outcrop especially on the northern side of the Baba Darwes mountain, where the beds are well exposed and contain megafossils (see Palaeontological Appendix 2), mainly brachiopods, while the limestone of the middle to upper horizons contain a more abundant macrofossil assemblage from which specimens can be collected in great numbers at the foot of the cliffs located to the south of the mountain crest.

Pratically all the beds of limestone are more or less rich in microfossils as shown below (see Palaeontological Appendix 1).

From the top to the base, starting from the northern side of the mountain towards the south and passing over the crest, the series is as follows:

— Erosion surface.

11. Limestone red, grey and brown, compact, organogenic with *Amphidonte decussata* (Goldfuss) and *Rectithyris subdepressa* (Stoliczka) (fossiliferous locality No. 9). The fossils were collected 1780 m above sea level to the south-east of Chenar-i-Gunjeshkhan. From the same locality

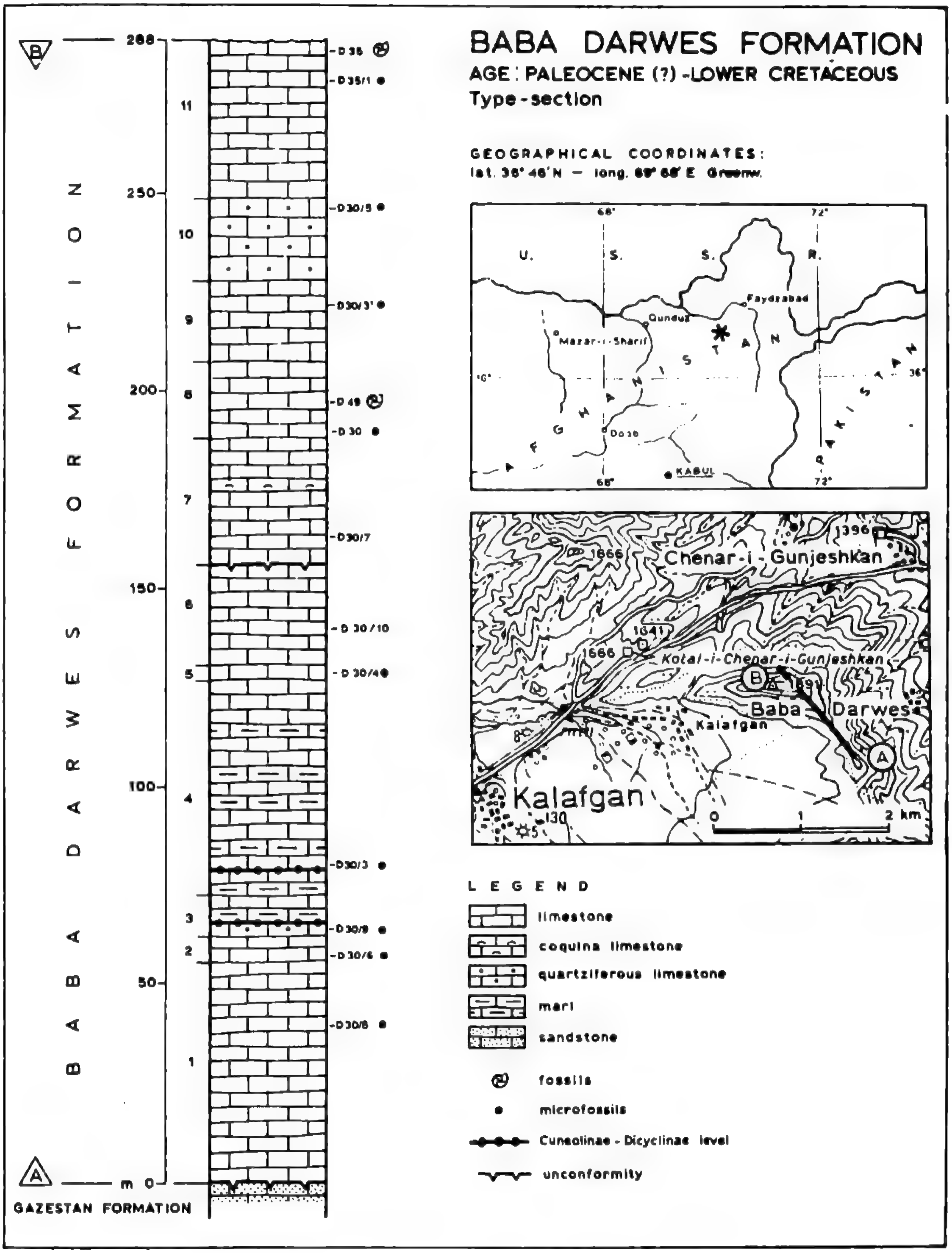

Fig. 12 - Type-section of Baba Darwes Formation.

another sample of brownish-grey limestone (biosparite) was collected (61 AD-35/1) with *Orbitoides, Lepidorbitoides,* rotalids, algae associated with bryozoa and molluscan fragments; several tens of metres thick.

10) Bed of compact, brown quartzose limestone (bio-intramicrite) with fragments of various shells, bryozoa, rotalids and *Orbitoides* (61 AD-30/5). thickness unknown;

9) Reddish-brown bioclastic limestone (foraminiferal bio-intramicrite) rich in bryozoa and algae; the foraminifera belong to the genera *Lepidorbitoides, Clypeorbis, Siderolites* (doubtful) and *Rotalia* (61 AD-30/3), thickness unknown;

8) Hard grey limestone with *Orbitoides, Siderolites,* rotalids, *Cibicides,* bryozoa (61 AD-49) and numerous megafossils including *Rectithyris odiumensis* SHANI, *R.* cf. *rotunda* SHANI, *R. subdepressa* (STOLICZKA), *Neithea (Neitheops) quinquecostata* (SOWERBY), *Lima canalifera* GOLDFUSS, *Pycnodonte vesicularis* LAMK., *Exogyra overwegi* VON BUCH, *Exogyra* sp., together with light grey limestone with foraminifera (including *Orbitoides media*) and byozoa (61 AD-30), several metres thick;

7) Grey limestone (intrasparite) with microfossils, including *Cuneolina* and *Dicyclina* possibly reworked (61 AD-30/7), about 25 m thick;

6) Compact fossiliferous light grey-brown limestone (biosparite) with rudists, nerineids and indeterminate brachiopods (61 AD-30/10), about 30 m thick;

5) Thick bed of bioclastic limestone (bio-intrasparite), grey, with yellowish alteration products, rich in crinoid remains (encrinite) and abundant bryozoa and molluscan remains; foraminifera are rare, mostly agglutinating tests; Lituolidae, *Cuneolina,* Rotaliidae, rare Calcisphaerulidae, *Stomiosphaera* (61 AD-30/4), 4 m thick;

4) Marl and red limestone (bio-intramicrite) with abundant molluss debris, calcareous algae, agglutinating foraminifera Ophthalmididae, Miliolidae, *Cuneolina, Dicyclina, Haplophragmoides* etc., rare ostracoda (61 AD-30/3), 50 m thick (?);

3) Yellowish quartzose limestone (micrite) slightly brecciated with rudist fragments, *Cuneolina,* Miliolidae, rare *Dicyclina* and Rotaliidae etc., (61 AD-

30/9); alternating with light grey-brown compact limestone with *Ichthyosarcolites triangularis* DESMAREST (61 AD-30 bis), 6 m;

2) Compact grey limestone with a thin bed of small *Exogyra* spp., at the base, with molluscan fragments, probable dasycladaceae, planktonic foraminifera, *Hedbergella* spp., *Stomiosphaera*, Rotaliidae (?) etc. (61 AD-30/6), 13 m;

1) Compact limestone (oo-intrasparite) light brownish-grey and maroon (61 AD-30/8) in beds a few tens of centimetres thick with mollusc and echinoderm fragments, rare foraminifera (Lituolidae, Ophthalmididae). Jurassic fossils such as *Saccocoma* and *Calpionella* have been found as reworked fossils in some beds at this horizon, 60 m;

— Gazestan Formation.

The section has a total thickness of about 290 m.
Numerous fossil specimens were collected at various points on the slopes without the possibility of their being assigned to the beds from which they where derived. The species indentified are (1):

Trigonarca sp.
Pinna arata FORBES
Pecten sp. indet.
Neithea gibbosa (PULTENEY)
Pycnodonte vesicularis (LAMK.)
Lopha sp. indet.
Arctica calabra SEGUENZA
Afrodina plana (SOWERBY)
Ichthyosarcolites triangularis DESMAREST
Ichthysarcolites tricarinatus PARONA
together with rudists and indeterminable brachiopods.

OTHER SECTIONS. — North-east of the type-section, above the road which runs from Kishem to the pass of Chenar-i-Gunjeshkhan, about 6 km from the first locality, there are a series of hills, the slopes of which are interrupt-

(1) The fossils are descripted in the volume IV-2 of the scientific Reports of Desio's expeditions to the Karakorum and Hindu Kush. See also Palaeontological Appendix 1 and 2.

ed by the tops of limestone beds, forming a series of steps (Table II, fig. 1). These are the hills above the village of Mohammad Aba and are composed of three main massive limestone beds between which are intercalations of more or less calcareous marl. These are poorly esposed. Under this series, the shales and green and red sandstones of the Mohammad Aba Sandstone outcrop. In the series of overlying beds, which have an overall thickness or about 200 m, reddish coloured limestone horizons are repeated three times.

This section has not been completely surveyed, but certain horizons were distinguished from which fossils were also collected. From the base to the top these are:

a) Dark, tan-coloured, brecciated, fossiliferous limestone (61 AD-34) with *Pycnodonte vesiculosa* (SOWERBY), *P. vesicularis* LAMK. etc.;

b) Grey, glauconitic, fine-grained sandstone with a clayey matrix (61 AD-34/2) containing sponge spicules, rare mollusc shells and small planktonic foraminifera (*Hedgergella* spp.);

c) Partly brecciated limestone in various shades of tan, grey and red alternating with marly sandy beds which are poorly exposed;

d) Yellowish-white limestone (61 AD-34/1) (biomicrite) fossiliferous, with *Cuneolina* and agglutinating foraminifera such as *Haplophragmoides, Textulariella* etc., together with *Pycnodonte vesicularis* (LAMK.), *Trigonia* sp. indet., *Aphrodina plana* (SOWERBY), *Pleurotomaria* sp. indet., *Haustator multiplicatus* PCELINCEV, *Trochactaeon matensis* (FITTIPALDI).

This last horizon is the highest of the local series and corresponds to horizon 4 of the type-section.

Other fossils collected in the vicinity (61 AD-34) include the following species:

Trigonarca diceras (SEGUENZA)
Lima sp.
Pycnodonte vesiculosa (SOWERBY)
Pycnodonte vesicularis (LAMK.)
Amphidonte conica (SOWERBY)
Ichthyosarcolites sp. indet.
Indeterminate rudists.

Further to the west, between Kalafghan and Astana Tepa, the Baba Darwes Formation outcrops on the mountain 1804 m high (located 3 km east of Aq Bulaq) and is about 200 m thick. The limestone with intercalations of reddish coloured marls (near the base) rests on the Mohammad Aba Sandstone, while at the top the surface is eroded.

Here, on the northern summit of the ridge which descends towards the north from the trigonometric point 1804.4, in the grey limestone (61 AE-69) *Arctica* sp. indet., and *Ceratostreon spinosum* (MATH.) were collected.

Still further to the west the Baba Darwes Formation rests on top of the Gazestan Formation and is represented by a few tens of metres of limestone which, towards the top, is truncated by the transgressive contact of the Kokcha Formation. Here, above the rock-salt mine of Astana Tepa (Kalafghan a specimen of *Pycnodonte vesiculare* (LAMK.) (61 AD-54) was collected.

On the slope in front of Gazestan, in the Baba Darwes limestone a specimen of *Pinna arata* FORBES (61 AE-80) was collected, but not in situ, a form which ranges from the Turonian to the Senonian.

A stratigraphic section surveyed on the slope which rises to the north of the road junction for Farkhar, on the road from Taluqan to Kishem, displays the following sequence from top to bottom [1]:

— Taluqan Gravel.

2) light grey limestone (biomicrite passing into fossiliferous micrite with molluscan fragments) rich in foraminifera, *Cuneolina*, *Dicyclina* etc. (61 AE-87/12), 40 m thick;

1) marly-sandy limestone (micrite with quartz grains) yellowish-grey (61 AE-87/11) with numerous *Amphidonte columba* (LAMK.) and foraminifera, 40 m thick;

— Gazestan Formation.

Here therefore the Baba Darwes Formation has a thickness of only 80 m as the result of erosion which removed the upper part of the formation before the deposition of the Kokcha Formation.

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(1) Detailed descriptions of microfacies is contained in the Palaentological Appendix 2. The fossils are described in the IV-2 volume of the present collection.

In addition, in the altered rocks of the same locality in which the fossiliferous micrite (unit 1) with *Amphidonte columba* (LAMK.) was collected in situ, the following fossils were also collected (61 AE-87/13).

Pycnodonte vesicularis (LAMK.)
Amphidonte columba (LAMK.)
Amphidonte conica (SOWERBY)
Inoceramus sp. indet.
Thomasites sp. indet.

Particularly interesting is the presence of ammonites belonging to the genus *Thomasites,* which is confined to the Lower Turonian. Finally, in extreme south-western part of the area mapped, that is in the Farkhar valley, the Baba Darwes formation consist of some tens of metres of compact grey limestone, which rests on the Gazestan Formation and is covered unconformably by the Taluqan gravel. On the road from Taluqan to Faydzabad, 3 km east of Taka Toymast, the limestone contains indeterminate echinoids together with *Pycnodonte vesiculare* (LAMK.) (61 AD-15).

In some places the top of the formation shows, for a few metres, a characteristic structure produced by the fracturing of the calcareous beds into large blocks scattered at random on the surface. This structure was probably produced during a continental period, perhaps during the Tertiary, after the deposition of the limestones of the Baba Darwes Formation and before the deposition of the conglomerates of the Kokcha Formation.

AREAL DISTRIBUTION. — The Baba Darwes Formation outcrops in the area between Mohammad Aba, Jeldragh and Kalafghan, near Aq Bulaq and in the belt situated on the northern flank of the Shor river valley (downstream from Astana Tepa) until it crosses the Farkhar river just east of Taka Toymast.

Proceeding from north-east towards the south-west, that is from the Kishem valley to the Farkhar valley, the Baba Darwes Formation overlies first the Mohammad Aba Sandstone, then the Gazestan Formation.

AGE. — As will be clarified in the Micropalaeontological Appennix, the fossils present in the lower horizons of the section represent Albian (?), Cenomanian and Turonian without the possibility of distinguishing one from another. Since small *Hedbergella* spp., are present it is suggested that ho-

rizon 2 belongs to the upper part, possibility of a Cenomanian age. The successive horizons from 3 to 5 inclusive are securely assigned to the Cenomanian by the presence of *Cuneolina* and *Dicyclina* together with *Ichthyosarcolites triangularis* DESMAREST, a rudist typical of the Cenomanian. Horizon 6, at least the upper part, seems to be referrable to the Turonian. The higher horizons 8, 9, 10 and 11, are referred with certainty to the Maastrichtian because they contain such microfossils as *Orbitoides, Omphalocyclus, Siderolites, Lepidorbitoides* and also because of the presence of megafossils indicative of the Senonian such as *Exogyra overwegi* VON BUCH, *Rectithyris odiumensis* SAHNI, *Rectithyris subdepressa* (STOLICZ.). In conclusion the attribution of the first five (lower) horizons to the Albian (?) — Cenomanian and the topmost four horizons to the Maastrichtian is well documented. However, there are no palaeontological indications for the interval between the two. Therefore, a hiatus corresponding to a large part of the Turonian and Senonian sequence is advanced as a working hypothesis.

Horizon 7 may be interpreted as corresponding to the transgressive horizon, which includes fragments belonging to the underlying Cenomanian — Turonian rocks (e.g. *Cuneolina* and *Dicyclina*). In this respect it is interesting to observe that certain Russian authors have recognised the existence of an analogous hiatus in Tadzhikistan.

Finally, it should be mentioned that the horizons of the Baba Darwes Formation above 11, destroyed by erosion, must have extended up into the Palaeocene.

The other outcrops of the Baba Darwes Formation compare well with the ages found in the type-section. Thus the horizons above the village of Mohammad Aba have a similar palaeontological content and correspond to the type section up to horizon 6 (Cenomanian—Turonian) and also the fossils collected from isolated localities fall within the same age range.

The locality between Kalafghan and Astana Tepa has furnished only one identifiable species, *Ceratostreon spinosum* (MATH.) which is not present everywhere, but is a Senonian species which means that the outcrop corresponds to the upper part (horizons 8-11) of the type-section; and also the Gazestan exposures.

Even better characterised from the point of view of the chronostratigraphy is the outcrop at the road junction to Farkhar, where there is a typ-

ical Turonian fossil (*Thomasites*) and others such as *Inoceramus* which may represent *Inoceramus labiatus* SCHLOTH. present elsewhere (Pull-i-Khumri, Barfaq), which confirm that these beds are attributable to this level.

THE RELATIONSHIPS WITH THE BLUTI FORMATION. — The highest horizon of the stratigraphic sequence of the Baba Darwes Formation is represented, as stated above, by red limestone (horizon 11) which forms the southern side of the Chenar-i-Gunjeshkhan pass. The beds dip towards the north, thus proceeding in that direction one passes through younger strata.

North of the pass, near Jeldragh, red shales are widespread which may represent the beds of the Ambar Koh red series. On the geological map they have been assigned to the Baba Darwes Formation, but perhaps represent a different formation, widely distributed and very thick to the west of Ambar Koh, in eastern Kataghan.

On this latter mountain, as will be discussed below, it was possible to examine a sufficiently detailed section which provided macro- and microfossils enabling dating of the various beds to be accomplished. The basal horizons represent the Palaeocene, thus they overlie chronostratigraphically the highest beds of the Baba Darwes Formation.

On the other hand the fossils collected from the Bluti formation are referable, as will be seen below, to the Middle to Upper Eocene (Alai-Turkestan), thus, if this formation is not transgressive on the Baba Darwes Formation, there must be beds intermediate between the two which are referable to the Palaeocene (in the area the Lower Eocene is missing as a result of a hiatus). If one considers that in the Ambar Koh series the Palaeocene is present, parhaps the red marls in the Jeldragh area, north of Chenar-i-Gunjeshkhan, belong to the same stratigraphic level.

2.8. Bluti formation (Bf). (1)

INTRODUCTION. — In an earlier paper (DESIO, MARTINA & PASQUARÈ, 1964) this formation was identified as the *Kharakan Formation*; later, in the « Le-

(1) The name « formation » is written without a capital letter since it is an informal litostratigraphic unit.

xique Stratigraphique International » (U.R.S.S., vol. II, fasc. 2, 1958, p. 606), it was discovered that this name had already been assigned to another formation in Central Asia (Kazakhstan) belonging to the Middle Ordovician (Karakan Formation). On account of the similarity of the two names and because of the priority of the Russian one we have used here the name of Bluti formation in order to avoid misunderstanding. Furthermore, the village bearing the name of Kharakan on the 1:50.000 maps to the north-west of Kalafghan is known by the inhabitans as Bluti, while another village named Kharakan is located in the Kokcha valley which is not far avay.

LITHOLOGY. — A type-section cannot be described for this formation shows only small outcrops and too incomplete sections are present in the area examined. The locality where this formation was identified is 7 km north of Kalafghan and 2.5 km north of Bluti, about 69° 55′ east Long. and 36° 49′ north Lat. Proceeding from the village of Lower Jeldragh towards the east a ridge appears, the upper and lower parts of which consist respectively of massive white limestone (61 AD-37_1) with small miliolids and light-grey limestone with calcite veins (61 AD-37_2). The limestone beds are quite thick and dip to the south-southwest at 50°. At the top of the ridge (about 1700 m) several fossils were collected (61 AD-65) which are referable to *Ostrea* (*Turkostrea*) *afghanica* VIALOV, *Fatina* (*Fatina*) *böhmi böhmi* (VIALOV), *Fatina* (*Sokolowia*) *esterhazyi esterhazyi* PAVAY, partim VIALOV. About one kilometre to the west-southwest, on the same ridge at about 1720 m, another fossiliferous locality was found: *Ostrea* (*Turkostrea*) *afganica* VIALOV, *O.* (*Turkostrea*) *cizancourti* COX and *Fatina* (*Sokolowia*) *esterhazyi buhsei* (GREW) were collected (61 AE-66).

On the hills to the west and south of the same ridge the limestone beds overlying the red clayey-arenaceous marls and marking the passage to the Baba Darwes Formation are present as numerous scattered blocks on the marls. The same limestone beds outcrop on another ridge further to the west.

The Bluti formation is unconformably overlain by the conglomerate of the Kokcha Formation which almost entirely masks the rocks which form the passage to the Baba Darwes Formation.

It cannot by excluded, however, that the outcrops of Baba Darwes Formation at Bluti emerge through a series of green and pink marls and mainly red sandstones, younger than the fossiliferous limestone. Lack of expo-

sures, the rolling nature of the topography, the extensive cover of the rocks of the Kokcha Formation and the short time devoted to the investigation of this area, did not allow a more detailed study. In this connexion it should also be said that on the Ambar Koh, just to the west of Taluqan and therefore outside the Badakhshan, fossiliferous beds with a marly arenaceous facies of the same age outcrop which have been given the name of Ambar Koh Formation and described subsequently (page 118).

This latter formation is probably present also in the vicinity of Jeldragh where alternatively it may be represented by a cover of red continental deposits which overlie the Sumsar marine series in the Tadzhikistan.

Areal Distribution. — No other outcrops of the Bluti formation are known outside the area previously mentioned. It would appear that, moving westwards, the calcareous facies which prevails in the Bluti formation is gradually replaced by the marly facies (Ambar Koh Formation, Member A).

Age. — The fauna collected at both fossiliferous localities is probably of the same age and belongs to the Middle—Upper Eocene. More precisely, of the three species from the first locality *Ostrea afghanica* is essentially a Lutetian species, while the other two are Priabonian (Turkestan stage). Of the three species present at the second locality, the two Ostreae belong to the Lutetian and the *Fatina* to the Priabonian; therefore, on the basis of this small amount of data it should be stated that the Priabonian and the passage to the Lutetian are present at the first locality and viceversa at the second locality. However, the palaeontological data are too poor to provide conclusive evidence although it is known that both the Middle and Upper Eocene are present in that region; that is, Vialov's Alai and Turkestan stages as recorded for the nearby region of Tadzhikistan. For comparisons with similar formations present in neighbouring regions see chapter on Ambar Koh Formation (page 118).

2.9. Kokcha Formation.

Introduction. — The Kokcha Formation is more than 1100 m thick and consists of thick beds of conglomerate interbedded with usually greyish

sandstone and marl containing fragments of echinoids, rare *Bathysiphon* sp. and ostracodes belonging to the lacustrine genus *Candona*. The pebbles in the conglomerate are black slate, amphibolite, quartz, granodiorite, tonalite, diorite, marble and Cretaceous limestone, occasionally with rudist impressions.

The conglomerate grades upwards and laterally, from the edge to the centre of the sedimentary basin, into arenaceous and marly beds.

The beds consisting mainly of sandstone and conglomerate were called the *Tah Jari Member* (Kf) (Plate IV), those consisting of marl and sandstone, the *Ghelawuk Member* (Kf'). Locally, between the Mashad and the Hazara valleys, a characteristic conglomerate facies is present which was also mentioned by Brückl (1935). It consits of very large boulders of granodiorite, tonalite and diorite cemented by arkosic sand. This facies was called the *Ganda Qol Member* (Kf"); it appears to continue, according to the geological map of Hinze (1964), to the south-west of Farkhar along the edge of the Upper Amu Darya Depression oriented NE-SW (Taqcha Khana–Chal–Iskamesh).

The Kokcha Formation outcrops extensively in the Kokcha valley downhill from Qara Kamar, in the Mashad valley downhill from Kishem, and in the ridges overlooking to the north the villages of Kalafghan, Astana Tepa and Gazestan. In particular, the Ghelawuk Member outcrops in the Kokcha valley downhill from Artin Jelaw where the conglomerate describe a light anticline (fig. 13); the Tah Jari Member is exposed in the Kokcha valley between Artin Jelaw and Qara Kamar, and also limits the outcrops of the Ghelawuk Member to the south. Finally, the Ganda Qol Member outcrops, as already stated, between the Mashad and Hazara valleys, limiting the outcrop area of the Kokcha Formation to the east.

On the whole, the Kokcha Formation forms a large flat syncline the axis of which is approximately oriented south-west along the course of the Kokcha river.

Previous Knowledge. — Barthoux (1933) mentioned and assigned to the Miocene some « grès redressés du Miocène avec intercalations fréquentes de conglomerates » outcropping near Kishem which, undoubtedly, correspond to the Kokcha Formation. Popol and Tromp (1954), and Desio (1960)

dated the « Siwalik series » of northern Afghanistan, which could correspond to the Kokcha Formation, as Pliocene [1].

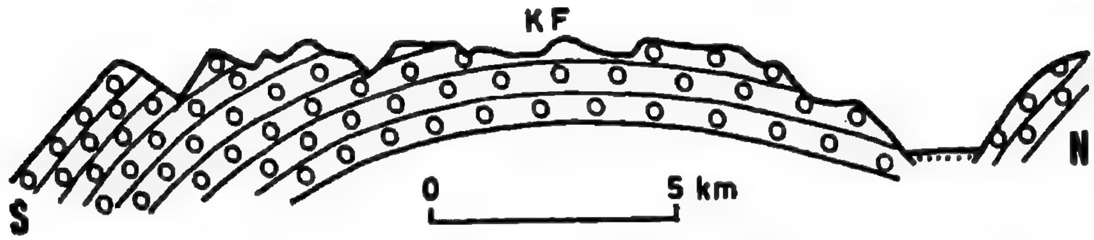

Fig. 13 - Anticline of the Kokcha Conglomerate (KF) on the right-hand slope of the Kokcha valley downstream from Artin Jelaw (from Desio's field book).

Hinze (1964, page 53) described a clastic formation which outcrops in the Kataghan region and was called by him « Schuttserie », which he dated as Oligocene—Miocene—Pliocene (?); most of this formation corresponds to the Kokcha Formation. This author, however, also included in his « Schuttserie » the uppermost beds of the Ambar Koh sequence, that is the « red rocks » which the Russian authors in Tadzhikistan assigned to the Khanabad-Sumsar stage transgressively overlain by the Kokcha Formation.

Type-Section of the Ghelawuk Member. The type-section of the Ghelawuk Member was measured along the course of the Mashad river downstream from Kishem, between the confluence with the Wakhshi and the Kokcha rivers (Fig. 14), at 70° 03′ east Long. and 36° 55′ north Lat.

The section is 1120 m thick and, from the top to the bottom, presents the following sequence:

16) grey sandy marl (61 AE-60/1), with abundant tabular crystals of mica and rare *Bathysiphon* sp., 10 m;

15) grey sand with scarce argillaceous-calcareous cement (61 AE-60/2) and fragments of quartz, mica, calcite, 10 m;

14) sand with argillaceous cement (61 AE-60/3) and fragments of mica and quartz, 15 m;

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(1) It is not possible to establish an age-correspondence between continental deposits so far away from the type-area (the Siwalik Hills are in the Sub-Himalayan belt); more particularly, since the Siwalik of India extends over a longer period of time, that is from the Middle Miocene to the Pleistocene (*Lexique Stratigraphique International,* vol. III, fasc. 8, page 243), it is preferable to use a local nomenclature.

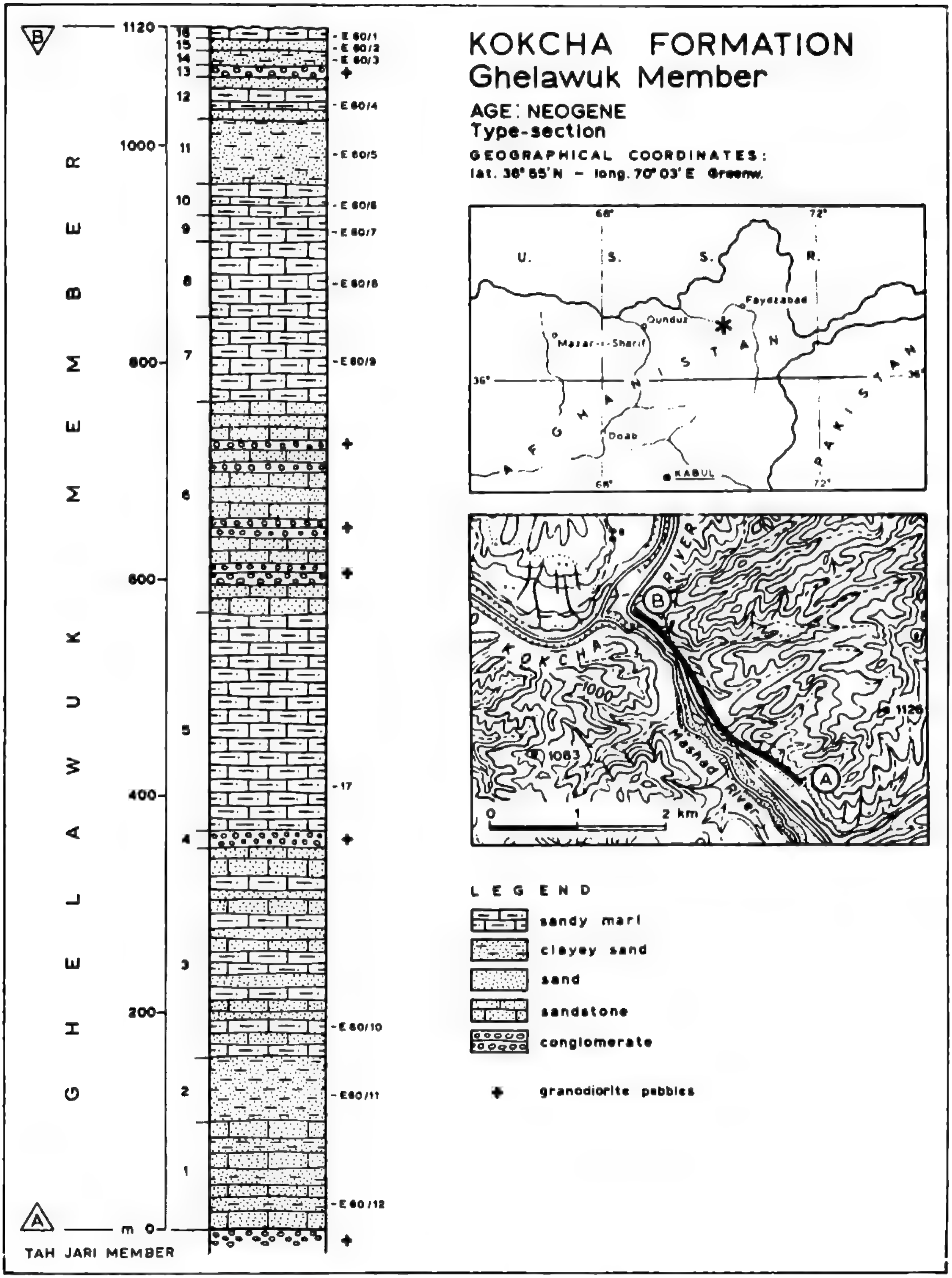

Fig. 14 - Type-section of the Ghelawuk member of the Kokcha Formation.

13) conglomerate with pebbles up to 5 cm in diameter; the pebbles are black slate, granodiorite, marble, 10 m;

12) sand and grey arenaceous marl (61 AE-60/4), 40 m;

11) grey, argillaceous-calcareous sand (61 AE-60/5) the residue of which is rich in crystalline quartz, micas, green rocks, occasional *Bathysiphon* sp. and fragments of echinoid spines, 60 m;

10) grey, sandy marl (61 AE-60/6) with abundant ostracodes belonging to the lacustrine gen. *Candona,* badly preserved; abundant fragments of echinoids and some *Bathysiphon* sp.; perhaps agglutinating foraminifera, 30 m;

9) grey, sandy marl (61 AE-60/7) the residue of which is rich in echonoid spines, probable *Bathysiphon* sp. and two ostracodes belonging to the lacustrine gen. *Candona,* 25 m;

8) grey, sandy marl (61 AE-60/8) not disaggregatable even in the finest fraction; quartz, mica and calcite are predominant; one echinoid fragment, 70 m;

7) grey, very sandy marl (61 AE-60/9) with coarse detrital fragments; the residue shows abundant biotite, muscovite and other micas, crystalline quartz, green rocks and calcite; rare *Bathysiphon* sp., 80 m;

6) sandstone, sand, greyish conglomerate with pebbles up to 5-8 cm in diameter; the pebbles are black slate, granodiorite, amphibolite (scarce) and marble; greyish sand with conglomerate intercalations, 200 m;

5) grey, sandy marl (61 A-17) with low organic content (quartz and mica); frequent *Bathysiphon* sp., 200 m;

4) greyish conglomerate with pebbles up to 7-10 cm in diameter; the pebbles are black slate, granodiorite, amphibolite, marble, 15 m;

3) sandstone, sand and sandy marl; the grey sandy marl (61 AE-60/10) has rounded grains of quartz as its constituent and mica. *Bathysiphon* sp. are frequent together with other calcareous elongated shapes, partly fragments of echinoids and partly bryozoans, 195 m;

2) grey, argillaceous sand (61 AE-60/11) with very fine detrital grains, rich in quartz and mica, 60 m;

1) argillaceous sand and grey sandstone (100 m); the argillaceous sand (61 AE-60/12) is rich in quartz grains with rounded corners, micas and green rocks.

Along the road from Faydzabad to Kishem, between Artin Jelaw and the mouth of the Mashad river in the Kokcha valley, (samples 61 AP-170 to 177) the grey, marly horizons of the Ghelawuk Member were sampled; careful inspection of the samples revealed only one fragment of an echinoid in sample 61 AP-172.

Tah Jari Member, Beyond the Kokcha river the series continues into the Diwar-i-Tang valley towards Masukhan village with lithologies similar to those of the Ghelawuk Member, but with sandstone and conglomerate.

STRATIGRAPHIC POSITION. — The Kokcha Formation is transgressive with its Tah Jari Member on the limestone and marl of the Bluti formation to the north of Kalafgan, and on the Baba Darwes Formation (Jeldragh, Kalafghan, Elftaw, Koh-i-Namak, Archa Kotal, Gazestan and Taka Toymast). In the Koh-i-Namak region (near Astana Tepa) the Kokcha Formation (still with its Tah Jari Member) is transgressive on the Gazestan Formation.

In the extreme north-east of the area of outcrop (between the Kokcha and the Hazara valleys) the Kokcha Formation (still with the Tah Jari Member) rests upon the Farkhar Slate: to be precise, near Qara Kamar (in the Kokcha valley), the reddish conglomerates of the Tah Jari Member, a few metres thick, overlies the Farkhar Slate nonconformably. Wherever the conglomerates belonging to the Kokcha Formation nonconformably overlie the calcareous sediments of the Baba Darwes limestone, they have a characteristic reddish colour, visible also at a distance, as in the valley to the north-west of Kalafghan, above Bluti village.

Finally, it must be mentioned that in the area between the Mashad and the Hazara valleys the Kokcha Formation overlies, with the Ganda Qol Member, the Farkhar Slate (between Kishem and Ganda Qol and in the Hazara valley) and the igneous bodies of the Jalmish Tonalite between the Teshkan and the Darayem valleys.

The top of the Kokcha Formation has been in most places eroded away; only in the extreme south-west of the area surveyed (near Gazestan, Taluk, Jigdami and Shorcha) the Kokcha Formations is covered by the angular unconformable Taluqan Gravel.

AGE. — The age of the Kokcha Formation, unconformably overlying the fossiliferous deposits of the Bluti formation of Middle—Upper Eocene age (Alai–Turkestan stage), must be younger than Upper Eocene. Furthermore, in the region between Khanabad and Taluqan, to the west of the area investigated, the Kokcha Formation unconformably overlies also a considerable thickness (abouth 700 m) of reddish argillaceous, marly and arenaceous deposits. These sediments, on the Ambar Koh, seem to represent, at least in part, the Oligocene and seem to correspond to the « red continental series » belonging, according to the Russian authors, to the Khanabad-Sumsar stage (Upper Eocene, Oligocene and perhaps partly also Miocene). Therefore it can be deduced that the Kokcha Formation is of Neogene age. Moreover, the Russian authors refer a thick continental formation, which also contains pebbles with rudist fragments and analogous to the Kokcha Formation, to the Tertiary. This formation overlies either Paleogene, Mesozoic or Palaeozoic beds. Calcareous pebbles with fragments of rudists (61 AE-68) were also found during this survey in the conglomerate overlying the Bluti formation and belonging to the Tah Jari Member.

REMARKS. — Although it is very difficult to correlate continental deposits, it could be useful to search for some elements, common to the Kokcha Formation, in the area to the north of the Amu Darya; these elements could be of use in defining more precisely the age of the above mentioned formation. The Kokcha Formation, also with re namely the « Polizak Suite », referred compared with two other formations,gard to lithological composition, can be to as Pliocene, in the Tadzhikistan and Darvaz regions, and the Kurteka Formation which, in southern Pamir, represents the Pliocene and an indefinite part of the Miocene (V. A. VASIL'YEV, 1965). These two formations are considered to be partly contemporaneous. The first is overlain by the Kulyab complex, ascribed to the lower Quaternary, containing bone fragments of mammals and hand-made objects of Acheulean age; the second one is overlain by the Bakmal-Dzhilga complex representing the lowest part of the Quaternary. Although we do not have any certain evidence, it is possible that in the Kokcha Formation parts of these two complexes are also represented.

2.10. Taluqan Gravels (Tgr).

The type-section, about 300 m thick, was surveyed along the valley of the Taluqan river, near Khatayan and east of Taluqan, at 69° 40′ east Long. and 36° 38′ north Lat.

The section consists of an alternating sequence of fine and coarse gravel beds up to 20 cm in diameter, occasionally slightly cemented and with graded bedding. The estimated thickness is 200 m.

The stratigraphical position of the gravels, which overlie the Kokcha Formation with an angular unconformity, the lithological composition of the

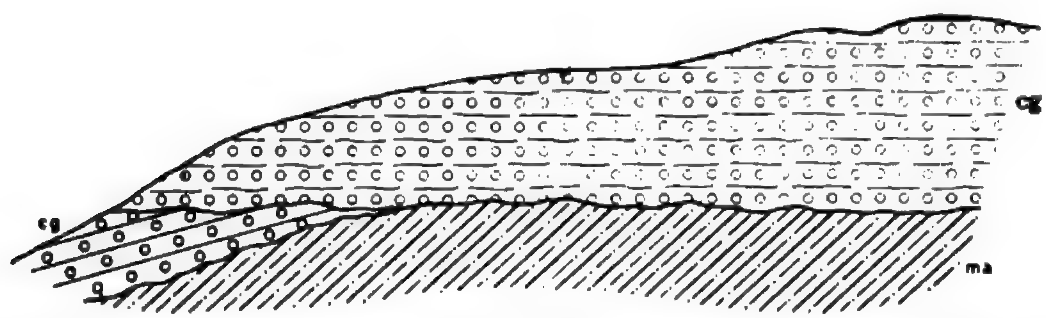

Fig. 15 - Gravel weakly cemented (Taluqan gravel, bc) overlying the Kokcha conglomerate (cg) and the green marls and red sandstone (ma) of the Ambar Koh Formation to the west of Jeldragh.

pebbles and cobbles (Fig. 15) (black slate, quartz, granodiorite, diorite, quartz-diorite, marble and Cretaceous limestone) and the perfect rounding of the gravels itself, all suggest that the Taluqan gravels must be considered as an erosion product of the Kokcha Formation. Therefore the Taluqan formation belongs to the Pleistocene.

The Taluqan gravels outcrop in the area to the west of the Shor valley and on the hills to the north of Kalafghan. The Taluqan gravels rest unconformably on the Kokcha Formation near Kalafghan, at Chakal, at Taluk, at Jigdami and Shorcha; on the Baba Darwes and Ambar Koh formations at Jeldragh, at the Chenar-i-Gunjeshkhan pass, in the Taluqan valley near Taka Toymast, and on the Gazestan Formation near Aq Bulaq (Fig. 16).

The Taluqan gravels will be discussed in the chapter describing the Pleistocene deposits.

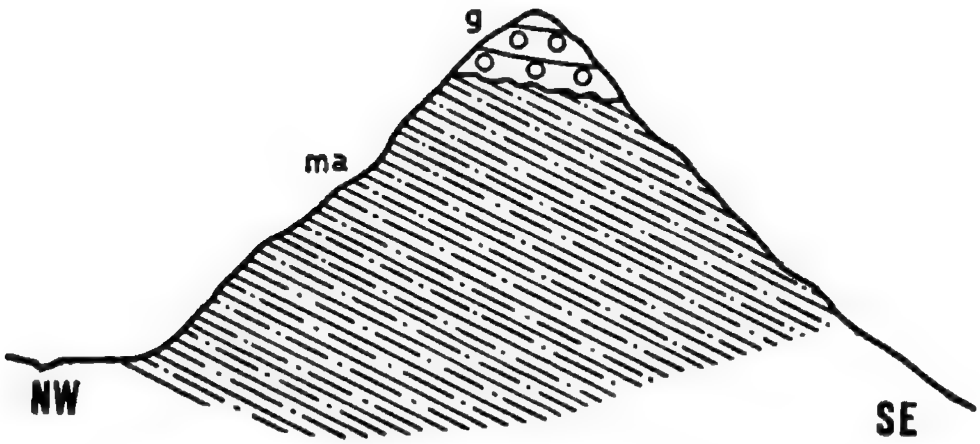

Fig. 16 - Geological section across a hill about 8 km east of Khanabad (from DESIO's field book). (ma = red marls of Ambar Koh Formation; g = Taluqan gravels).

γ. SOME STRATIGRAPHICAL SEQUENCES IN KATAGHAN AND IN THE SURROUNDING REGIONS.

1. INTRODUCTION.

As already mentioned in the introduction to this report, stratigraphic studies were carried out in several areas lying just to the west of Badakhshan and in other regions of northern Afghanistan in order to solve some particular problems, chiefly stratigraphic ones, which arose during the investigation of the studied area. Lack of time and other difficulties prevented us from fully carrying out our investigations so that the data collected were often incomplete. Notwithstanding these difficulties, new data about the stratigraphy of northern Afghanistan were collected and are presented in this chapter.

The problems are those concerning our knowledge of the oldest stratigraphic horizons belonging to the sedimentary series to the west of Faydzabad, and particularly of the Jurassic ones which are best exposed in Kataghan. Also interest lies in the most recent marine horizons belonging to the same series, that is those of Palaeocene and Eocene age which have few and badly exposed outcrops in the Badakhshan province and therefore are poorly presented on the geological map enclosed with this report. In this connection DESIO and PASQUARÈ surveyed a stratigraphic se-

quence in the Karkhar region to determine the relationships between the Jurassic and Cretaceous marine beds present at this locality (Desio, 1960). These studies have enabled us to correlate the chronologically identified basal horizons with the Karkhar ones now accurately dated. This work was also carried out because, at the time, it was not known that geological studies had been started in the same regions and the reports by G. Gabert and L. Benda had not yet been published. For the same reason E. Martina was asked to carry out a thorough stratigraphic study of the Pull-i-Khumri Formation of Cretaceous age, in order to complete the mapping of the lowest horizons and of the upper part of the stratigraphic sequence outcropping above Barfaq, both already described in a previous report by Desio (1960). These sporadic investigations have enabled a correlation to be made between the Pull-i-Khumri Cretaceous formation and its coeval formations outcropping in Badakhshan.

Other stratigraphic investigations were carried out in several areas of Kataghan and Mazar-i-Sherif with the purpose of achieving a thorough knowledge of the Bluti formation and its relationship with the underlying and overlying beds; in the area of our study all the data collected were incomplete and doubtful on account of the unfavourable geological setting.

More surveying was carried out by Martina near Ali Abad where Desio collected some fossiliferous samples belonging to the Paleogene (Desio, 1960) while visiting the Shiboglu Kotal area, underlain by formations of Eocene age, and surveying a stratigraphic section further to the west, near Tashkurghan; both localities are particularly rich in fossils. Between 1961, the year of our expedition, and the publication of this report several works concerning the area investigated by us have been published by German and French geologists. We refer to them throughout the text.

2. STRATIGRAPHIC SEQUENCE OF THE KARKAR FORMATION (Kf) (JURASSIC).

Previous Knowledge. — The Karkar region is well known to geologists who have worked in Afghanistan because the first evidence of marine Jurassic sediments in a complex (Saighan Series) which, up to that time, was thought to be entirely continental was found there. R. Furon and L. F. Rosset were the first to discover marine fossils at Karkar.

FURON and ROSSET announced in a short geological report (1954) the discovery of a marine fossiliferous horizon of Jurassic age in the Karkar area, about 24 km north-northeast of Pull-i-Khumri. The determination of the fossils collected by ROSSET was made by FURON. Nine species were identified and the fauna was largely attributed to the Bajocian and Bathonian, to be more specific, belonging to the *Parkinsonia parkinsoni* — *Oppelia aspidoides* zones etc.

When in Kabul in 1954, DESIO made the acquaintance of L. F. ROSSET, who in that year and again in 1955 presented him with some samples of yellowish-grey fossiliferous limestone. The fossils were examined by C. ROSSI RONCHETTI and N. FANTINI SESTINI, and were mentioned in a preliminary paper by A. DESIO in 1960, further they were illustrated in a report by the two mentioned authors (1961).

During the 1961 expedition, DESIO and PASQUARÈ collected numerous other fossils in the same locality. ROSSI RONCHETTI examined the new specimens and revised the whole fauna from Karkar in a memoir published in the volume IV-2 of the present series (1970).

The fauna illustrated by ROSSI RONCHETTI consisted of the following species:

Chomatoseris porpites (W. SMITH)
Montlivaltia cf. *caryophyllata* LAMOUROUX
Montlivaltia cornutiformis crassa GREGORY
Montlivaltia cottreaui (COLLIGNON)
Montlivaltia culullus GREGORY
Montlivaltia cyclolitoides MILNE EDWARDS & HAIME
Montlivaltia decipiens (GOLDFUSS)
Montlivaltia gregoryi ALLOITEAU
Montlivaltia numismalis (D'ORBIGNY)
Montlivaltia sp.
Acanthothyris sp.
Burmirhinchia hsenwiensis BUCKMAN
Sphenorhynchia sp. aff. *plicatella* (SOWERBY)
Oxytoma cf. *inaequivalve* (SOWERBY)
Ascitoma sp.
Meleagrinella echinata (W. SMITH)
Placunopsis socialis MORRIS & LYCETT

Ctenostreon rugosum (W. SMITH)
Camptonectes annulatus (SOWERBY)
Camptonectes rigidus (SOWERBY)
Camptonectes sp. ind. cf. *C. laminatus* (SOWERBY)
Camptonectes richei DECHASEAUX
Camptonectes sp.
Plagiostoma cardiiforme (SOWERBY)
Plagiostoma subcardiiforme GREEPPIN
Pseudolimea duplicata (SOWERBY)
Liostrea aduliformis (SCHLOTH.)
Nanogyra crassa (W. SMITH)
Nanogyra nana (SOWERBY)
Trigonia cf. *pullus* SOWERBY
Lucina cf. *rotundata* (ROEMER)
Protocardia sp. ind.
Pronoella desioi ROSSI RONCHETTI
Pronoella karkarensis ROSSI RONCHETTI
Eomiodon gardeti MONGIN
Pleuromya uniformis (SOWERBY)
Pleuromya sp. ind.
Corbula sp. aff. *daghaniensis* COX
Corbula sp.
Homonya douvillei ROSSI RONCHETTI
Myopholas acuticosta (SOWERBY)
Pholadomya hemicardia ROEMER
Pholadomya lirata (SOWERBY))
Pholadomya sp. aff. *deltoidea* (SOWERBY)
Cossmannea (*Eunerinea*) *pasquarei* ROSSI RONCHETTI
Colastracon (*Ovactaeonina*) *phasianoides* (LYCETT)

According to the author, the above-quoted species exhibit a rather wide chronostratigraphic distribution, which is however included within Bathonian and Callovian, but, with the specimens collected by our 1961 expedition, the new conclusion is that « the horizon of origin of the fossils, and particularly level 5 of the type-section, are assignable to the most recent horizons of Bathonian ».

DESIO recorded in his 1960 report on Afghanistan that among the

samples which had been given him by ROSSET one was accompanied by the following words: « Dalle calcaire crétacée surmontant l'Oolithe à Karkar ». This samples is composed of a beige coloured limestone containing *Inoceramus* cf. *labiatus* SCHLOTH.

According to the paper by FURON & ROSSET, the Jurassic fossiliferous limestone would be about 50 m thick and would be overlain by 60 m of fossiliferous limestone. This last would in turn be overlain by gypsiferous claystone, several hundred metres thick, which has been referred to the Lower Cretaceous by the above-mentioned authors. DESIO concluded that the limestone with *Inoceramus* probably originated from upper layers which were analogous to those of the Pull-i-Khumri sequence described in the same paper.

Such was our knowledge on the Karkar locality, before the DESIO's expedition to North-East Afghanistan in 1961. Only the age of the fauna was perfectioned with the study of the new fossils by ROSSI RONCHETTI.

The results of the stratigraphic investigations carried out by us during the 1961 expedition are described in a short report by DESIO, CITA and PREMOLI SILVA published at the end of 1965; this report contains the type-section of the new formation and lists its microfauna and microfacies. In the meantime the works of GABERT and BENDA were published (1964) but they were made available to us only during June 1966, six months after the publication of our report [1].

TYPE-SECTION. — It is considered sufficient to describe here only the stratigraphic sequence surveyed by us and published in 1965 which represents the type-section of the Karkar Formation and is used here to correlate its Cretaceous horizon with the ones present in Badakhshan. The geographical coordinates are: 68° 48′ east Long. and 36° 03′ north Lat. The sequence of the Karkar type-section is, from top to bottom, the following (Fig. 17):

32) thick-bedded, fine to medium-grained, grey-brown sandstone (61 AP-178/35) alternating with bioclastic and oolitic limestone (61 AD-178/34) fossil fragments and foraminifera; the upper part consists of uniform green-brown but mainly grey limestone (61 AP-178/36) more than 20 m;

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(1) See page 54, note 1.

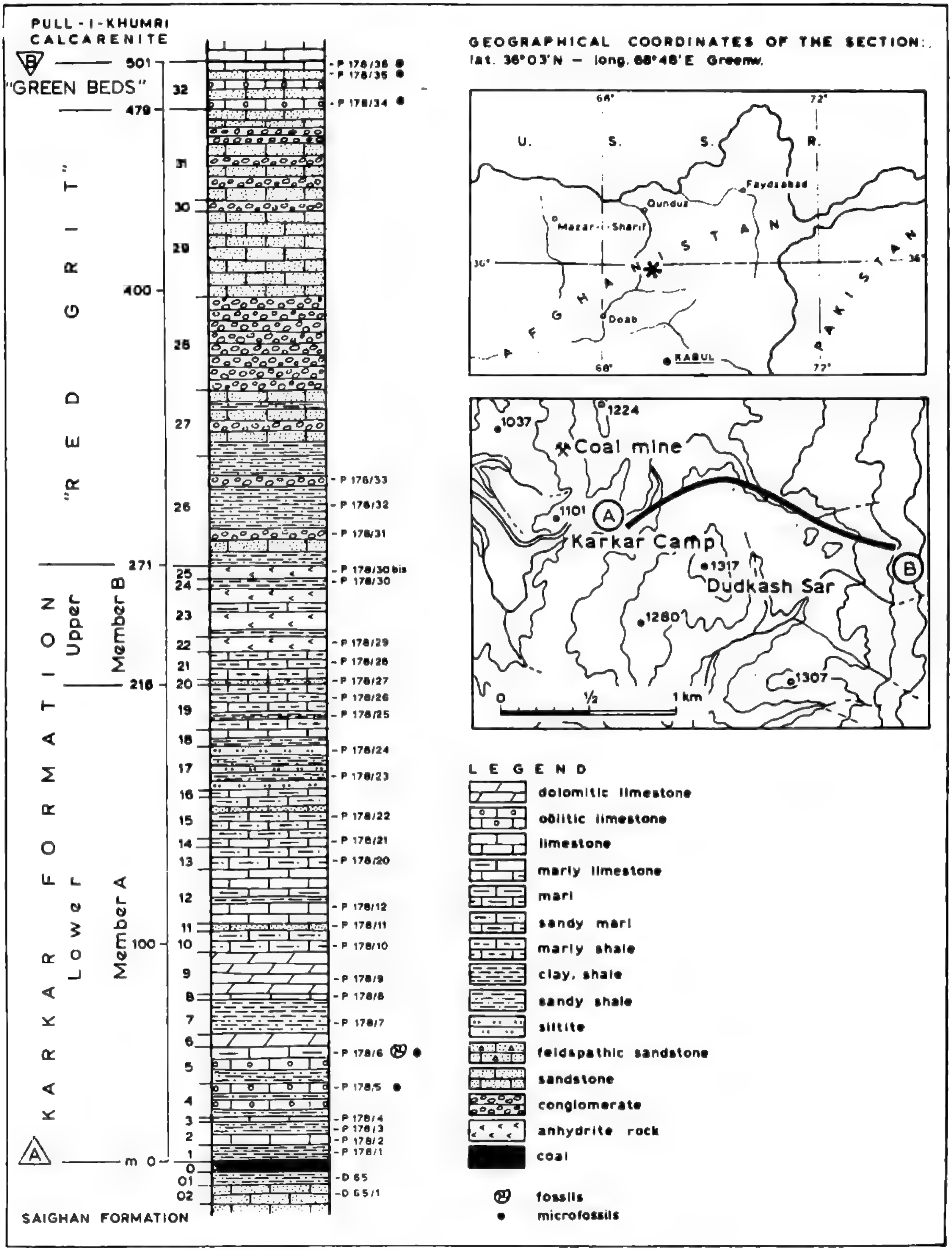


Fig. 17 - Type-section of the Karkar Formation.

31) red, grey-green, variegated, fine-grained sandstone alternating with conglomerate consisting of pebbles larger than 5 cm in diameter occasionally cemented together by an abundant red, arenaceous matrix or by a scarce, light grey-brown calcareous-arenaceous matrix, 41 m;

30) conglomerate with small amounts of grey-brown arenaceous cement; the pebbles are quartz and sandstone with also some marl and red and green shales derived from the underlying beds, 6 m;

29) red and green, poorly bedded, fine-grained sandstone, with pebbles less than 5 cm in diameter near the base, 39 m;

28) coarse bedded conglomerate with cobbles up to 10 cm in diameter cemented by a reddish, sandy matrix. Occasionally the components of the conglomerate are angular, 43 m;

27) sandy shale grading upwards into conglomerate; beds up to 1.50 m thick, 29 m;

26) dark wine-red, massive or friable, laminated sandy shale (61 AP-178/32) with scattered quartz and sandstone pebbles grading into conglomerate (61 AP-178/31 and 33) consisting mainly of limestone, quartzite, rhyolite, dacite etc., 50 m;

25) white, thick-bedded, massive anhydrite (61 AP-178/30 bis) with grey, grey-green and brown veins, 6 m;

24) reddish and green shales (61 AP-178/30) with some calcite veins, 4.5 m;

23) green and red, white banded, powdery anhydrite with different, often brecciated textures with intercalated thin beds of red-green shales and marls, 24 m;

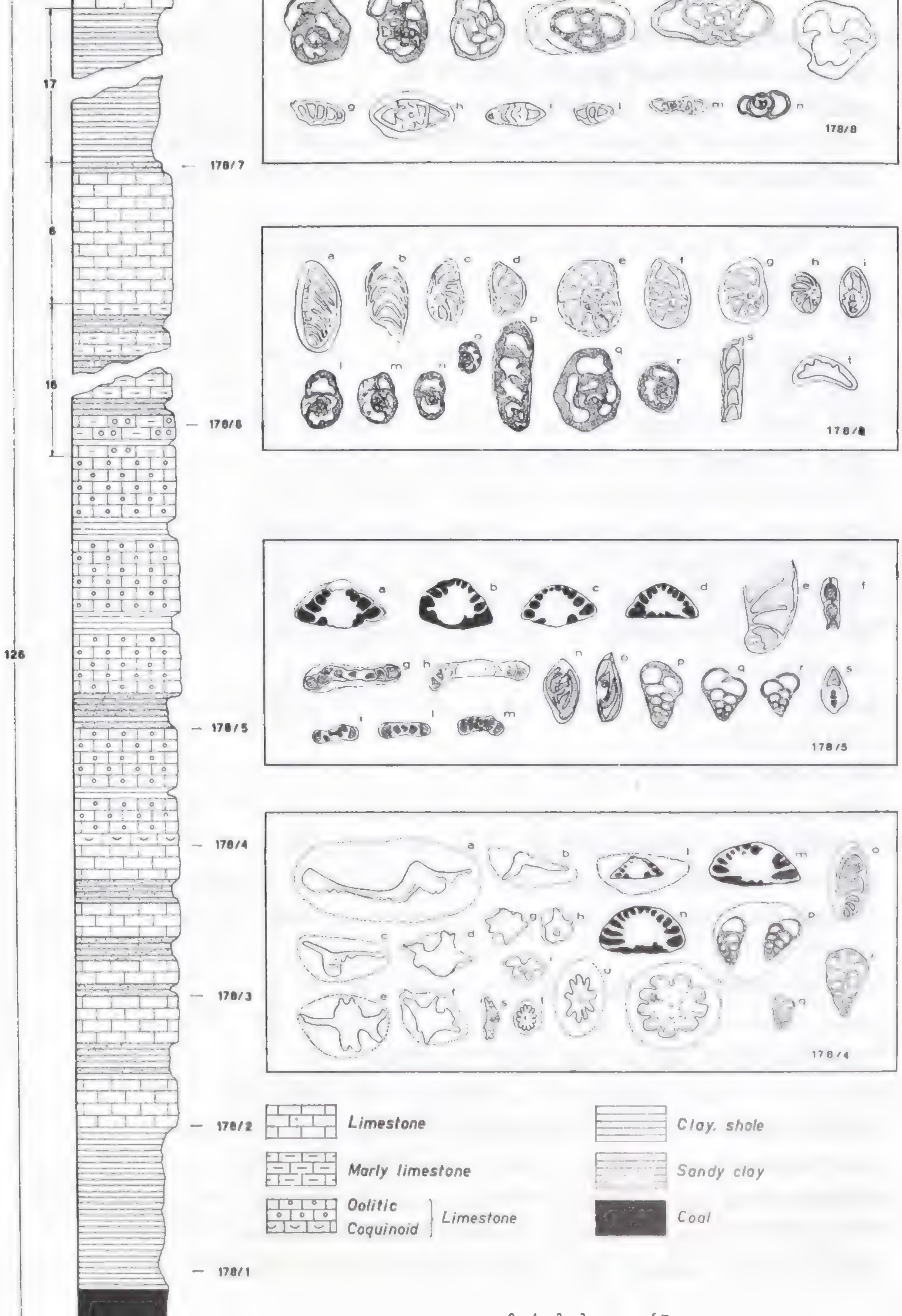
22) white, grey-green or grey-brown, banded, thick-bedded anhydrite (61 AP-178/29) with intercalated thin beds of red or green shales and marls, 5.5 m;

21) reddis and green, variegated, slightly marly clay (61 AP-178/28) with anhydrite lamellae, 13 m;

20) thin beds of green faldspathic sandstone (61 AP-178/27) alternating with clay similar to level 19, 2 m;

19) reddish and light-green, slightly marly clay (61 AP-178/25) with occasional thick beds of wavy lamellae of clay and anhydrite (61 AP-178/26), 20 m;

18) light grey-green, homogeneous limestone with a few intercalations of beds of reddish and green shales, 8 m;
17) reddish and green, foliated, sandy shales (61 AP-178/23) alternating with grey-green siltstone (61 AP-178/24); the shales contain thin concretionary beds of calcite which increase in thickness upwards (40 cm), 20 m;
16) thick beds of brown, brecciated, marly limestone with abundant large gasteropods, 2.5 m;
15) light reddish, slightly arenaceous marl (61 AP-178/22) with green beds; two beds of red, fine-grained sandstone are present 12 m above the base, 18 m;
14) light green, homogeneous and massive limestone (61 AP-178/21) with fossil fragments in beds 20-80 cm thick, 3.5 m;
13) red and light green, normally foliated sandy marl (61 AP-178/20), 10 m;
12) light grey and light brown, massive, waxy limestone (61 AP-178/12) with rare fragments of foraminiera (*Lenticulina* sp.), crinoids and *Inoceramus* are present in beds 30-50 cm thick; in the middle of the sequence an intercalation of ash-grey, foliated, marly limestone is present associated with some beds of red clay, 25 m;
11) thin beds of ash-grey, sandy marls and fine-grained sandstone (61 AP-178/11), 3.5 m;
10) red, sandy marl (61 AP-178/10), 11 m;
9) light grey, massive, crystalline dolomitic limestone (61 AP-178/9), occasionally brecciated, in beds 20-50 cm thick, 18 m;
8) grey, well-bedded limestone with abundant organic remains (61 AP-178/8) including rare foraminifera and *Saccocoma* with limonite staining, 2 m (Fig. 18);
7) red clay grading, at the base, into sandy clay, 17 m;
6) grey, massive, slightly waxy dolomitic limestone (61 AP-178/7), with small calcite veins, in beds 20-40 cm thick, 6 m;
5) grey-brown marly limestone, occasionally foliated, with zones of oolite and a coquina of small pelecypods, foraminifera (Lagenidae such as *Lenticulina* cf. *quenstedti* Gümb., *Vaginulina* aff. *ovata* ESPIT & SIGAL, *Frondicularia* sp., Lituolidae such as *Haplophragmoides* sp. and *Ammobaculites* sp., *Saccocoma* sp.; the limestone alternates with greenish-white, foliated, sandy clay. The species of pelecypods collected in situ



17
6
16
126
178/7
178/6
178/5
178/4
178/3
178/2
178/1
178/8
178/5
178/4
Limestone
Clay, shale
Marly limestone
Sandy clay
Oolitic
Coquinoid
Limestone
Coal

are the following: *Camptonectes richei* DECHA., *Plagiostoma cardiiformis* (SOW.), *Pseudolimea duplicata* (SOW.), *Placunopsis socialis* MORRIS & LYCETT, etc. At about ten metres above the base a rock-lens with *Ostrea* sp. is present. All the other fossils came probably from the same beds where DESIO collected his specimens separately, and among them: *Plagiostoma subcardiiformis* (GREPPIN), *Ctenostreon rugosum* (W. SMITH), *Nanogyra nana* (SOW.), *Pholadomya hemicardia* ROEMER, *Ph. lirata* (SOW.), *Pleuromya uniformis* (SOW.), etc., 16 m;

4) light oolitic limestone (61 AP-178/5), alternating with white to green sandy clay, with abundant organic fragments and *Globochaete alpina* LOMB., foraminifera (*Trocholina conica* SCHLUM. etc.), and *Saccocoma* sp., 16 m;
3) grey-brown coquina and oölitic limestone (61 AP-178/4) with *Trocholina conica* (SCHLUM.) and fragments of echinoids, 0.5 m;
2) brecciated limonitic limestone (61 AP-178/2) with small gasteropods, in beds 20-30 cm thick alternating with white to green sandy clay (61 (AP-178/3) showing some carbonaceous material, 12 m;
1) well foliated, greenish-grey and red, variegated shale (61 AP-178/1), 7 m;

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0) Lens of black coal ranging in thickness from 2 to 9 m;

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01) Several metres of white, arenaceous shale (61 AD-65);
02) Several metres of red and greenish, fine-grained sandstone (61 AD-65/1).

The sequence described above may be, from top to bottom, stratigraphically divided as follows:

Pull-i-Khumri Calcarenite:

— beige-coloured limestone with *Inoceramus* cf. *labiatus* SCHLOTH. Marine (neritic) environment.

«Green beds»:

32- fine to medium-grained sandstone alternating with limestone; more than 20 m. Marine (coastal) environment.

~~~~~~~~~~ Unconformity ~~~~~~~~~~

«Red Grit»:

31-26- red sandstone and conglomerate; more than 208 m. Deltaic environment.
~~~~~~~~~~

Karkar Formation:

25-20- clayey-marly B member with anhydrite; 55 m. Lagoonal environment.

19-1 - calcareous-arenaceous-clay. A member; 216 m. Marine (neritic) environment.

Unconformity

Saighan Formation:

0 - coal; few metres thick;

01-02- red and green sandstone and white arenaceous shale; several metres thick. Continental environment.

As regards the age of the formations, it can be stated that the uppermost bed represents the base of the Pull-i-Khumri Calcarenite which was described by Cita and Ruscelli (1959), Desio (1960) and Rossi Ronchetti (1961), and referred to the Turonian, with the exclusion of the lower beds which seem to belong to the Cenomanian.

The underlying beds may be considered as a reduced section of the « Green beds » which Hayden (1911) assigned to the Cenomanian.

The red arenaceous-conglomeratic formation is the equivalent of the « Red grit » of Hayden (1911) and is dated as Lower Cretaceous.

The age of the lower fossiliferous beds is the same as that revelated by the paleontological studies carried out by Rossi Ronchetti (1970), i.e. Upper Bathonian. Therefore most of the Karkar Formation belongs to the Upper Jurassic: only the basal beds include the upper part of the Middle Jurassic. The underlying Saighan Formation (Hayden, 1911) was divided by Popol and Tromp (1954) into three membres: Upper, Middle and Lover Saighan. The coal measures seem to be frequent in the lower part of the Middle Saighan; therefore, if the coal measures of Ishpushta and Karkar are homotaxial — as it is probable — both belong to the Middle Saighan. Then the Karkar Formation should be the marine equivalent of the continental Upper Saighan the Saighan Formation is generally considered to be of Upper and Middle Jurassic age, the underlying Upper Doab being referred to the Lower Jurassic. Our conclusion, based on the marine fauna of the Karkar Formation, is the same.

According to data provided by Gabert (1964), the coal measures, in most parts alternating with carbonaceous shale, are present at different levels and, according to palaeontological determinations by Benda (1964),

contain near Dudkash *Nilssonia orientalis* HEER, *N. saighanensis* SEW., *N.* cf. *curvifolia* JACOB & SHUKLA, *N. afghanensis* BENDA (?), *Ptilophyllum* sp. (A). This fossil flora was assigned to the Middle Jurassic.

The stratigraphic series of Karkar and Pull-i-Khumri, described in this same chapter, have also a common horizon. Horizon 32 of the Karkar section, that is the uppermost one, corresponds, as far as the microfacies is concerned, to horizon 13 of the Pull-i-Khumri A section (page 107). Horizon 13, as will be seen later, is considered to be of Upper Cretaceous age, probably Cenomanian.

REMARKS. — It is worth remembering here that a stratigraphic series similar to the Karkar one is present in the Upper Amu Darya Depression. In this area too (S. J. JL'IN et al., 1947) the Upper Jurassic is represented by a series of grey limestones with some intecalations of clays, marls and also coarse sandstone grading into conglomerates with ammonites of Callovian—Oxfordian age. This latter series is overlain by the « Haurdan series », which is an evaporitic series: the lower part is represented by dolomitized dark-grey limestones and red-brown, grey-green anhydrite and gypsum with terrigenous material, the upper one rock-salt overlain by clays. The gypsiferous formation which contains fossils of Kimmeridgian—Tithonian age outcrops, contrary to what happens to other Jurassic stratigraphic horizons, in many parts of the Upper Amu Darya Depression and also at Dashtidzhum (page 40).

3. STRATIGRAPHICAL SEQUENCES OF THE PULL-I-KHUMRI LIMESTONE (CRETACEOUS).

PREVIOUS KNOWLEDGE. — The first data on this Cretaceous sequence were collected by DESIO in 1955 (DESIO, 1961). The type-section for this formation was surveyed in the hill overlooking the village of Pull-i-Khumri and has a thickness of about a hundred metres. Samples from this section provided mega and microfossils which have enabled us to date it as Cenomanian and Turonian; in another calcareous horizon overlying this section, fossils were found which could indicate the Senonian.

D. WEIPPERT (1968) published a stratigraphic series of the same area,

but, as already mentioned, this author did not take into account the data already reported about this locality considering as new a stratigraphic series and a list of fossils described in one of his publications although a stratigraphic series with palaeontological data as significant as his had already been published in 1959 and 1961 (Cita & Ruscelli and Desio). Martina collected more data in order to complete the stratigraphic sequence and to correlate it more meaningfully than Weippert had done, with other sequences in northern Afghanistan. It is considered useful to describe here this type-section as it can be integrated with the others surveyed by Martina in 1961 and discussed later in this chapter. The type-section is, from top to bottom, the following:

13) light-brown fossiliferous calcarenite. The thin section shows a bioclastic, medium-grained rock with large fragments of mollusc shells. *Inoceramus* is recognizable among them. Few foraminifera are also present and belong to the Miliolidae and Rotaliidae; bryozoa also occur. The following species of macrofossils were recognized: *Gryphaea vesicularis* Lamk., *Liostrea rouvillei* (Coq.), *Exogyra columba* (Lamk.), *Ostrea incurva* var. *acutirostris* Nilsson, *Cytherea plana* (Sow.), 8 m;

12) Whitish and light-brown nodular calcarenite containing *Inoceramus labiatus* (Schl.) and var. *latus* Sow. In the same bed, a bioclastic brown-pink limestone contains fragments of *Inoceramus* shells and numerous foraminifera belonging to *Cuneolina* sp., *Dicyclina* sp. and Miliolidae, Textulariidae, 6 m;

11) brown, flaggy, marly calcarenite, 6 m;

10) calcarenite similar to that of horizon 11 with small *Exogyra* sp. and remains of echinoids, 6 m;

9) greenish, clayey marl, 3 m;

8) reddish, hard biohermal limestone and marl, 3-4 m;

7) greenish marl with thin beds of fine-grained breccia, intercalated, 3-4 m;

6) greenish, calcareous marl with some beds of greenish hard limestone intercalated, 15 m;

5) reddish, clayey marl, 2.5 m;

4) yellow and greenish, brecciated, arenaceous limestone with small calcite nodules, 17 m;

3) green, clayey marl with gypsum, 3.5 m;

2) greenish, nodular calcarenite with some thin interbeds of brown crinoidal limestone. In thin section the limestone appears as a bioclastic rock with very abundant fossil fragments of molluscs; echinoids, crinoids (stem segments), bryozoa and rare algae (Melobesia), 12 m;

1) yellowish-brown, occasionally cross-bedded calcarenite with small irregular echinoids, among them *Epiaster* cf. *henrichi* PER. & GAUTH. Other fossils, belonging to the Cenomanian, include *Plicatula fourneli* COQ. and *Exogyra conica* WOODS.

The sections surveyed in 1961 by MARTINA near Pull-i-Khumri village in the vicinity of the road leading to Doshi, are now described (Fig. 19). Although the sections are separate, they can be connected, however, to a total thickness greater than that measured in 1955.

Section A.

This stratigraphical section was surveyed 5 km south of Pull-i-Khumri village and a few hundred metres to the east of the road to Doshi, on the ridge descending towards the Baghai pass (Kotal Baghai). The geographical coordinates are: 68° 45′ east Long. and 35° 53′ north Lat. From the top to the bottom, the stratigraphical sequence is as follows [1]:

— erosion surface;

19) brown, dolomitised limestone (biosparite) (61 AE-97/12) with badly preserved fossils (molluscs, bryozoa, and echinoid fragments), in beds 20-40 cm thick, 4 m;

18) light-brown limestone (biosparite) (61 AE-97/11) with abundant clastic quartz and frequent oölites; also mollusc fragments, gasteropods, bryozoa and echinoid fragments, 8 m;

17) light, oölitic limestone (sandy and oölitic biosparite) (61 AE-97/10) with molluscs, echinoid fragments, and bryozoa, 4 m;

(1) The description of the microfacies is contained in the Palaeontological Appendix 1.

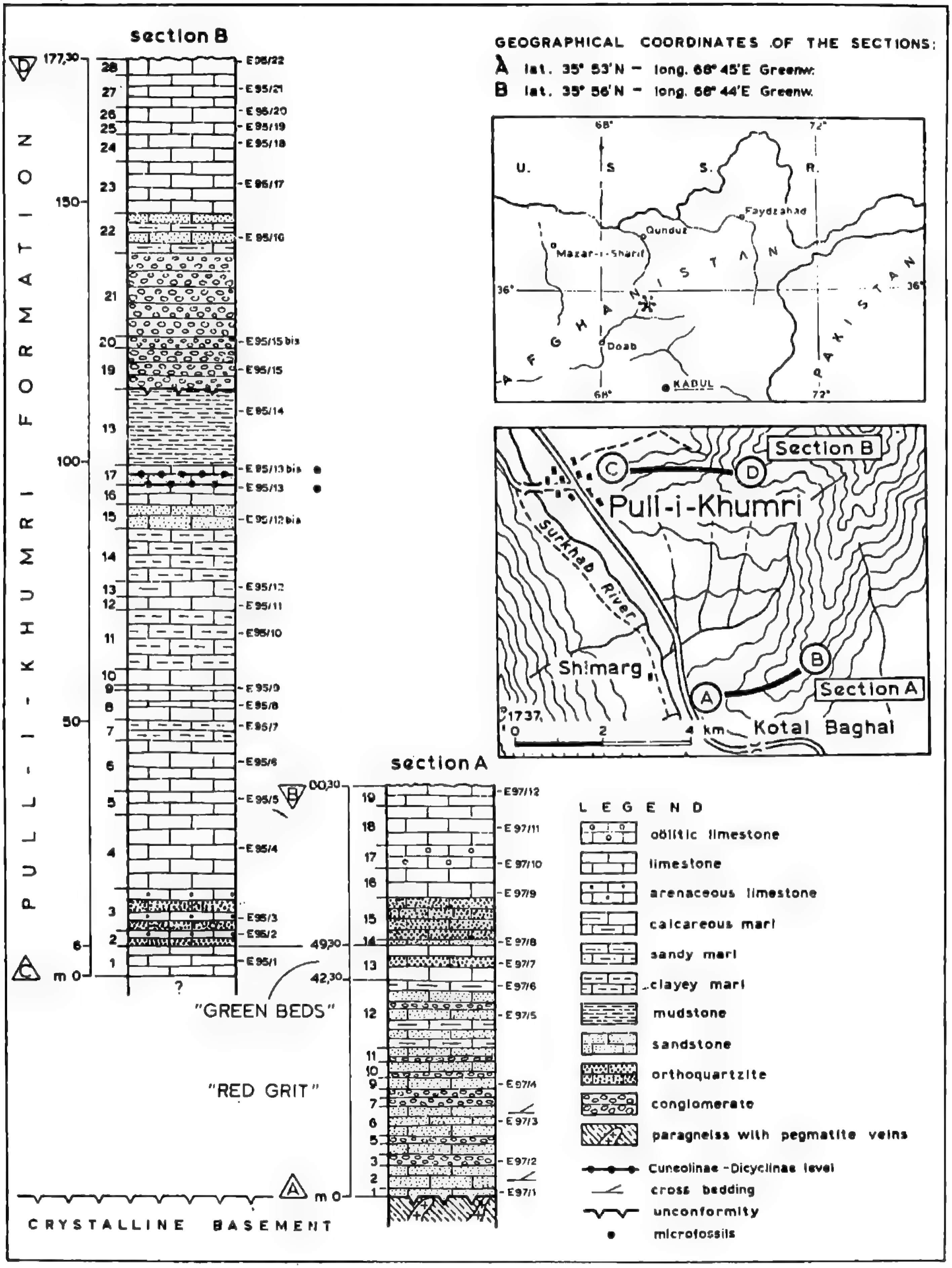

Fig. 19 - Stratigraphical sections of the Pull-i-Khumri Limestone.

16) brown, dolomitised limestone (biosparite) (61 AE-97/9) with clastic quartz, molluscan shells, echinoid spines and plates, bryozoa, 6 m;
15) yellow, foliated, well cemented sandstone, 8 m;
14) yellowish sandstone (61 AE-97/8) with calcareous cement (biosparite), oölites, molluscan shell fragments, 1 m;
13) yellow limestone (sandy oosparite) grading into sandstone (61 AE-97/7), with oölites and small unrecognizable organic fragments, 7 m;
12) yellowish sandstone (61 AE-97/5) with calcite and quartz grains grading into fine-grained conglomerate, alternating every 50 cm with bright red marl (61 AE-97/6) containing gypsum and calcite crystals, 13 m;
11) grey sandstone in beds 25 cm thick alternating with beds (1 m) of grey and reddish conglomerate with arenaceous cement and containing pebbles up to 8 cm in diameter, 3 m;
10) beds, 20 cm thick, of grey and red sandstone alternating with 20 cm thick beds of grey and reddish conglomerate with pebbles from 1 to 8 cm in diameter, 3 m;
9) light grey-green sandstone alternating, every 10-20 cm, with light grey-reddish sandstone (61 AE-97/4), 2.5 m;
8) greyish badly cemented conglomerate with arenaceous cement containing quartz and black schist pebbles up to 6-7 cm in diameter, 1.5 m;
7) greyish conglomerate with arenaceous cement containing quartz and black schist pebbles up to 6-7 cm in diameter, 1.2 m;
6) light grey-green, cross-bedded sandstone (61 AE-97/3) with many rounded quartz grains, calcite crystals and gypsum lamellae, 7 m;
5) greyish conglomerate with arenaceous cement containing quartz and black schist pebbles up to 6-7 cm in diameter, 1 m;
4) grey, marly sandstone, 2 m;
3) greyish conglomerate with arenaceous cement (61 AE-97/2) containing quartz and biotitic paragneiss pebbles up to 5-7 cm in diameter, 2 m;
2) greyish cross-bedded, marly sandstone with some grey-coloured pebbles of biotitic paragneiss, 6 m;
1) grey, marly sandstone (61 AE-97/1) with pebbles of biotitic paragneiss, 0.1 m;

— transgressive contact between the above sequence and the underlying grey biotitic paragneiss with pink plagioclasic pegmatitic veins.

The thickness of this sequence is 80.3 m.

At the base of the ridge, in the talus, a fragment of light-yellow, arenaceous limestone with some impressions of *Inoceramus* sp. was found (61 AE-99).

Section B. — This stratigraphical section was measured in the small valley just to the east of Pull-i-Khumri, above the village (Fig. 19). The geographical coordinates are: 68° 44′ east Long. and 35° 56′ north Lat. From the top to the bottom the stratigraphic sequence is as follows:

— eroded surface;

28) brown, dolomitised, impure limestone (biosparite) (61 AE-95/22) with corals, bryozoa, echinoid spines and plates, *Inoceramus* prisms and *Stomiosphera* spp., in compact beds 10 cm thick, 3 m;

27) light-coloured limestone (intra-biosparite) (61 AE-95/21) with molluscs, bryozoa, echinoids, *Stomiosphaera* spp., in compact beds 5 cm thick, 6 m;

26) brown limestone (intra-biosparite) (61 AE-95/20) with molluscan shells, echinoids, bryozoa, *Stomiosphaera* spp., in beds 5-10 cm thick, 3 m;

25) light-brown limestone (biomicrite) (61 AE-95/19) with fragments of molluscs, echinoids and bryozoa in beds 50 cm thick, 2.5 m;

24) light-brown, dolomitised limestone (biomicrite) (61 AE-95/18) with fragments of molluscs, echinoids and bryozoa in beds 80-100 cm thick, 5 m;

23) light-brown limestone (bio-intrasparite) (61 AE-95/17) with molluscan fragments, echinoid spines and plates, bryozoa, fragments of corals, rare agglutinating foraminifera, *Stomiosphaera* spp. in beds 20-40 cm thick, 10 m;

22) yellowish, very fine-grained quartz and mica sandstone with dolomite crystals (61 AE-95/16) and light-coloured, massive, slightly foliated, marly arenaceous limestone, 8 m;

21) whitish calcareous conglomerate, 16 m;

20) conglomerate with white calcareous cement (61 AE-95/15 bis) consisting of small pebbles of quartz, orthoclase, quartzite and chert. Fragments of molluscan shells are abundant in the sparry cement.

19) reddish, calcareous conglomerate (61 AE-95/15) consisting of quartz and black slate pebbles up to 5-7 cm in diameter, 8 m;

18) red and brown mudstone (61 AE-95/14) with gypsum and rare Lagenidae, 15 m;
17) red limestone (sandy intrabiosparite) grading into sandstone (61 AE-95/13 bis) containing quartz crystals, molluscan shells, foraminifera (*Cuneolina* sp., *Dicyclina* sp. Lituolidae, Miliolidae), 3 m;
16) light-brown limestone (biointrasparite) (61 AE-95/13) with molluscs and foraminifera (*Cuneolina* sp., *Dicyclina* sp., etc.), 4 m;
15) light-coloured, fine-grained sandstone (61 AE-95/12 bis) with quartz, mica, calcite, dolomite crystals, and fossil impressions, 5 m;
14) red, argillaceous marl, 10 m;
13) yellow, red and green calcareous marls (61 AE-95/12), 4 m;
12) yellow, compact limestone (sparite) (61 AE-95/11), 2 m;
11) red, argillaceous marl (61 AE-95/10) with rounded gypsum grains, bryozoa, and grey marl, 11 m;
10) yellow limestone (sparite) in beds 10-30 cm thick, 3 m;
9) yellow and white when altered limestone (biosparite) (61 AE-95/9) with abundant molluscan (?) fragments in compact beds 5-10 cm thick, 0,8 m;
8) yellow limestone (sparite) (61 AE-95/8) in beds 10-30 cm thick, 6 m;
7) bright red and grey, argillaceous marl (61 AE-95/7) with rounded fragments of red limestone, gypsum lamellae and crystals, ostracods, agglutinating foraminifera and gasteropod impressions, 4 m;
6) brown, fossiliferous limestone (oosparite grading into biosparite) (61 AE-95/6) with bryozoa, mollusc and echinoid fragments, in beds 5-10 cm thick, 10 m;
5) light-brown limestone (oobiosparite) (61 AE-95/5) with bryozoa, molluscan fragments and probable Dasycladaceae, in beds 5-10 cm thick, 4 m;
4) light-brown limestone (sandy biomicrite) (61 AE-95/4) with abundant bryozoa, molluscs, and echinoid fragments, in beds 5-10 cm thick 15 m;
3) brown limestone (sandy biosparite) (61 AE-95/3) grading into fossiliferous orthoquartzite, with molluscs, bryozoa and echinoid fragments, in compact beds 5 cm thick, 8 m;
2) yellowish limestone (sandy biosparite) (61 AE-95/2) grading into fossiliferous orthoquartzite with calcitic cement, with molluscan shells and bryozoa colonies, in thick beds, 3 m;

1) light-brown, foliated limestone (oosparite) (61 AE195/1), yellow when altered, with detrital quartz, in beds 10 cm thick, 6 m;

— alluvial deposits.

This section is 177.3 m thick.

These sections are particularly interesting since they enable a correlation to be made with the sequences of Cretaceous formations in Badakhshan. The correlations are based on studies of the microfaunas and microfacies carried out by CITA and PREMOLI SILVA. The first were published in the series IV, vol. 2 of this collection, the second in the Palaeontological Appendix 1 to this volume. First these correlations show that horizon 13 of the Pull-i-Khumri A section corresponds to horizon 1 of the B section, thus it is possible to add all section B to horizon 12 of the A section. The validity of this correlation is proved by the similarity of horizon 3 of section B and horizon 17 of section A. If it is borne in mind that the base of section A is represented by a clastic deposit marking the transgression of the sedimentary series onto the crystalline basement of this region, and the uppermost horizon of section B is fossiliferous and can therefore be dated, it is possible to establish a stratigraphic series, most of which is Cretaceous, 225.3 m thick (B = 177.3 m + A = 80.3 m = 257.6 m — 32.3 m in common = = 225.3 m).

Another correlation has also been established with the Karkar section described in the previous chapter. In fact horizon 13 of the Pull-i-Khumri A section corresponds to horizon 32, that is the uppermost part of the Karkar section. This means that beds 1-12 of the Pull-i-Khumri A section can be correlated with the beds underlying horizon 32 of the Karkar section. The thickness of beds 1-12 is, however, only 42 m: the crystalline basement underlies them. Underneath horizon 32 of the Karkar section there is a sequence about 1860 m thick. Between Karkar and Pull-i-Khumri, a distance of about 20 km, the crystalline basement therefore rises 1860 m. This explains why the Doab and Saighan formations are missing at Pull-i-Khumri.

It has not been possible to date directly horizons 1-12 of section A, but it is known that horizon 13 corresponds, according to the microfacies, to horizon 32 of the Karkar Formation type-section and to horizon 11 of the Qara Tut section belonging to the Gazestan Formation (at the base of the Baba Darwes Formation); both horizons can be assigned to the Lower Cre-

taceous-Cenomanian (?). Therefore, horizons 1-12 belong to the Lower Cretaceous-Cenomanian (?). The thickness of horizon 32 at Karkar is 20 m; the thickness of horizons 1-13 at Pull-i-Khumri is 48 m. Horizon 32 has been correlated with the « Green beds » which, in this area, are generally assigned to the Cenomanian (DESIO, CITA & PREMOLI SILVA, 1965). Beneath, the « Red Grit » occurs which, at this locality has been assigned to the Lower Cretaceous. It is probable that the « Red Grit » is present in horizons 1-12.

Such an interpretation is supported by the presence of red-coloured beds (horizons 9-12) which have a total thickness of 21 m. Underlying them there are 27 m of conglomerates and mostly grey sandstones which can not be correlated with any horizons of the Karkar Formation but which, on account of their direct contact with the crystalline basement, could be the equivalent of the Shingan conglomerate and the Qara Bulaq Sandstone outcropping in Badakhshan. Most probably, the clastic beds underlying the calcareous series of Pull-i-Khumri (horizons 1-12 of section A) should be correlated with the upper arenaceous-conglomeratic member (Archa Kotal Member) of the Mohammad Aba Sandstone: this member could represent locally the basal conglomerate of the Albian-Cenomanian transgression (?).

These new data add to our knowledge of the Pull-i-Khumri formation.

In fact, horizon 12 of DESIO's type-section can be correlated with horizons 16-17 of section B: both contain *Cuneolina* sp. and *Dicyclina* sp. In the upper parts of bath sections the presence of *Inoceramus* remains was noted, and in the lower parts calcareous algae. On the whole, it can be assumed that the type-section includes a series of beds which are equivalent to (and perhaps also greater than) the series of beds underlying horizon 16 of section B and to only a few metres of the overlying ones; consequently horizons 17-28 of section B could well represented the completion of the type-section. Good palaeontological determinations were used to date the type-section: the uppermost horizons belong to the Turonian, the lowermost ones to the Cenomanian. It was not possible to date the upper horizons of section B, but since the microfacies with *Cuneolina* sp. and *Dicyclina* sp. (horizons 16 and 17) is also present in the type-section of the Baba Darwes Formation, it is reasonable to assume that the uppermost horizons of the Pull-i-Khumri Calcarenite do not extend to the Maastrichtian, present at

Baba Darwes, and probably not even to the Campanian. However, as conglomeratic horizons 19, 20 and 21 mark a hiatus (which in the Baba Darwes section comprises a large part of the Turonian and Senonian sequence; this hyatus was also recognized in neighbouring Tadzhikistan by Russian authors), it follows that the upper horizons with bryozoa (22-28) of section B must represent a new sedimentary cycle including here a part of the Senonian (1).

4. THE CRETACEOUS AND PALAEOCENE SEQUENCE OF BARFAQ.

PREVIOUS KNOWLEDGE. — The first person to note the spectacular section along the old road from Kabul to Kunduz which passes Doab mountain and which displays a high rocky cliff face, was H. H. HAYDEN (1911). He has left us a photograph and a brief description.

DESIO (1961) provided a more complete description of the section in a note which is summarised below. The sequence is as follows:

7) White limestone with *Inoceramus labiatus* (SCHLOTH);

6) white hard bioclastic limestone with calcareous algae (*Lithophyllum*), foraminifera, (Textulariidae, Miliolidae), pelecypoda and gastropoda;

5) thin-bedded yellowish calcarenite;

4) yellowish calcareous conglomerate;

3b) green sandy clay;

3a) red sandy clay;

2) red conglomerate made up of pebbles of quartz, black slate, and green rocks;

1) Saighan series.

Horizons 2-5 are referred to the « Red Grit » and the « Green Beds » (Lower Cretaceous and Cenomanian), horizons 6-7 to the Turonian.

Horizon 7 has been correlated with horizon 12 in the type-section of Pull-i-Khumri because both contain the same species of *Inoceramus*.

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(1) For comparisons with this region see Appendix 2.

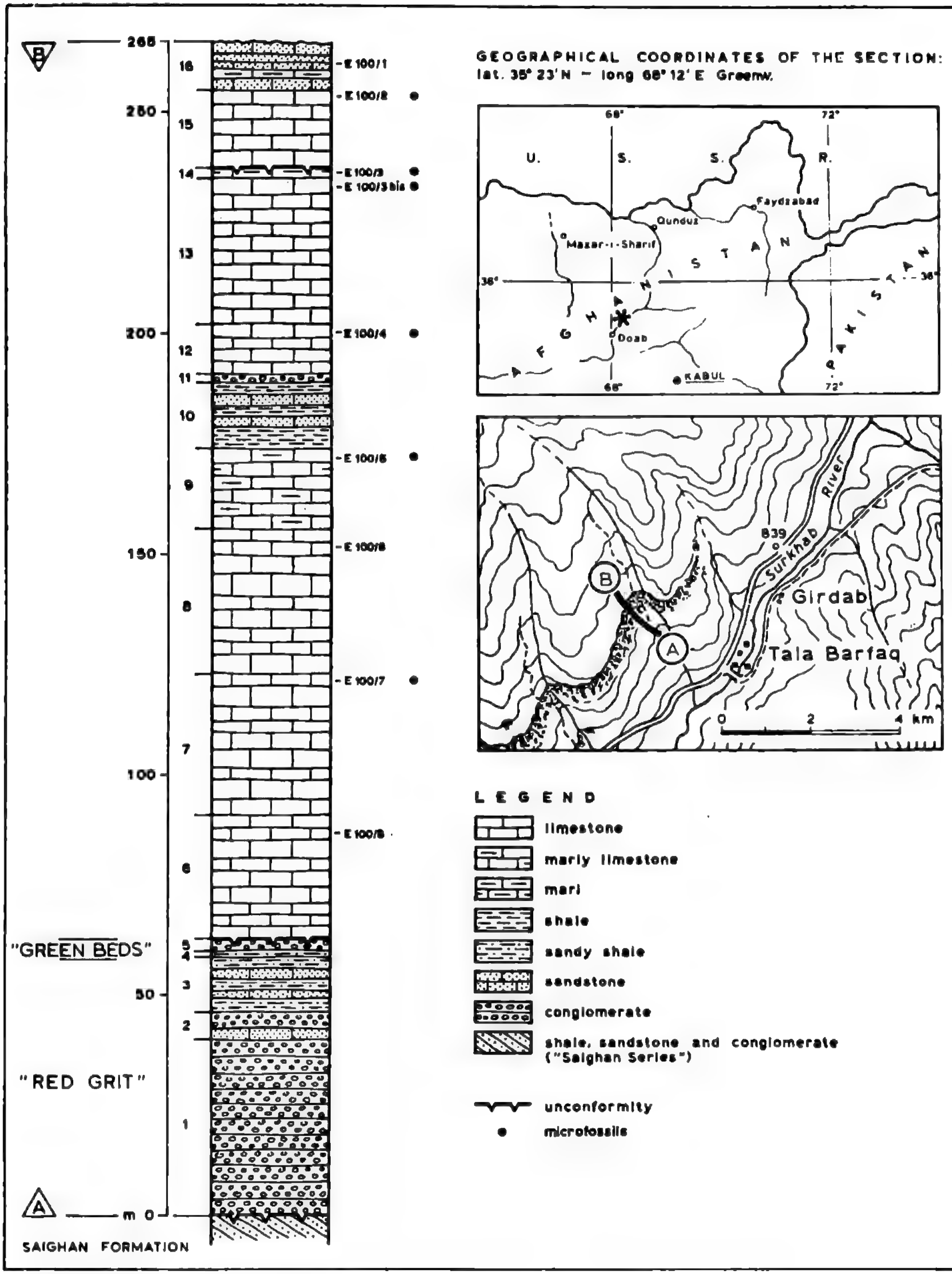

Fig. 20 - Stratigraphical section of the Barfaq sequence.

STRATIGRAPHICAL SECTION. — This stratigraphical section was surveyed in the Surkhab valley near the village of Tala Barfaq, on the precipitous western side of the valley immediately above the Doab—Doshi road (Fig. 20). From the top to the base the lithological succession is as follows [1]:

— erosion surface of the calcareous plateau;

16) quartz sand, with glauconite and mica flakes, with pebbles (often of sandstone), rare foraminifera like Miliolidae, *Cibicides*) (61 AE-100/1); with thin intercalated beds of sandstone and limestone, 10 m;

15) light coloured impure limestone (biosparite) (61 AE-100/2), with mollusca, echinoid fragments and bryozoa, *Cibicides*, Rotalidae, in 10-20 cm beds, 18 m;

14) greenish marl (61 AE-100/3), with arenaceous granules, glauconite, mica flakes, gypsum crystals, ostracoda and echinoid spines, a large indeterminate lamellibranch and abundant foraminifera (including planktonic species) *Marginulina, Lenticulina, Cibicides, Gyroidina* etc., 2 m;

13) compact brownish limestone (biosparite) (61 AE-100/3 bis) with miliolids and agglutinating foraminifera, *Cibicides*, molluscan and echinoid fragments, melobesid algae, 33 m;

12) light brownish limestone (intrabiosparite) (61 AE-100/4) with miliolids, agglutinating foraminifera, lagenids, rotalids, calcareous algae, molluscan fragments, 11 m;

11) yellowish limestone breccia, 2 m;

10) reddish sandstone and red clay, 15 m;

9) yellow more or less marly limestone (biomicrite) (61 AE-100/5) with abundant miliolids, large rotalids and agglutinating foraminifera, 18 m;

8) white impure argillaceous limestone (micrite) (61 AE-100/6) with pelletoid structure and containing rounded quartz grains in beds from 10 to 100 cm, 33 m;

7) yellowish limestone (partly pelletoid micrite) (61 AE-100/7) with abundant rounded quartz grains and large rotalids, in beds from 10 to 100 cm, 32 m;

6) yellow limestone (pelletoid microsparite) (61 AE-100/8) with abundant clastic grains (quartz crystals) in beds from 10 to 100 cm, 28 m;

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(1) The microfacies description is contained in the Palaeontological Appendix 1.

5) yellowish calcareous conglomerate, 3 m;
4) greenish sandy clay, 0.80 m;
3) red sandy clay with intercalations of red sand in beds of 20 cm thickness, 13 m;
2) reddish well cemented conglomerate, with rounded pebbles (up to 20 cm in diameter) of quartz, green rocks, dark slate; with intercalations of reddish sand with small pebbles, 6 m;
1) conglomerate as above, but poorly cemented, 40 m;

— unconformity.

Saighan Series.

The total thickness of the section is 264.80 m.

In the detritus at the foot of the escarpment where the section was measured, fragments of a limestone with casts of *Inoceramus* sp., were found which presumably are of the same species (*I. labiatus* Schloth.) as found by Desio in 1955.

Age. — The units 1, 2 and 3, totalling 59 metres, can be referred to the « Red Grit » (Desio 1961) because of their lithological characteristics, their colouration and also their discordant relationship on the « Saighan Series ».

Similarly units 4 and 5, totallling 3.80 m can be referred to the « Green Beds ».

Horizon 13 has a characteristic microfacies which corresponds to that of horizon 02 in the Ambar Koh section, to horizon 1 in the C section at Ali Abad, and horizons 2 and 4 in the Tashkurghan section (see Palaeontological Appendix 1).

The age of these horizons can be defined indirectly, since they overlie horizon 1 (of Maastrichtian age) in the Tashkurghan section and it underlies the beds with planktonic foraminifera of Middle Palaeocene age in Barfaq (horizon 14), Ambar Koh, Ali Abad A, and Tashkurghan sections, which indicates a Middle Palaeocene age.

It can therefore be demonstrated that the underlying horizons of the Barfaq section (from 6 to 12) are Cenomanian and Turonian (the latter because of the presence of *Inoceramus labiatus* Schloth.) and the overlying strata from Upper Cretaceous up to the Middle Palaeocene.

On the other hand horizons 15 and 16 in the Barfaq section, overlying

the erosion surface which indicates a significant break corresponding at least to the Upper Palaeocene (see Palaeontological Appendix 1) are possibily of post-Palaeocene age.

5. THE SEQUENCES OF THE AMBAR KOH FORMATION (EOCENE).

INTRODUCTION. — Ambar Koh (or Koh-i-Ambar) is a mountain about 20 km long, of ellipsoidal form with the major axis oriented towards the north, which rises north of the road from Taluqan to Khan Abad, in Kataghan. Its base is at about 600 m, and rises to a height of 1979 m above sea level.

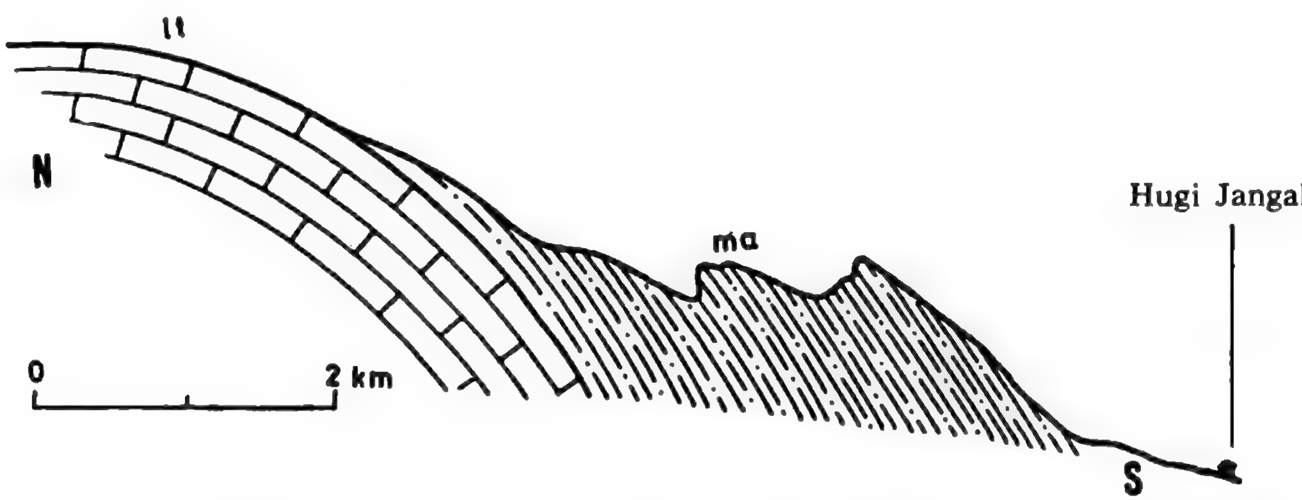

Fig. 21 - Geological section across the south slope of Ambar Koh (lt = Palaeocene limestone; ma = marl, sandstone and conglomerate of the Ambar Koh Formation).

The mountain has a general whale back profile, with the western side cut in part by a rocky wall (fault). There is a noticeable morphological contrast between the elevated parts of the mountain shaped like a dome and the lower slopes minutely broken up by erosion into numerous small valleys, ravines and trenches of varying size.

From the point of view of the tectonics the Ambar Koh is a brachyanticline eroded to its calcareous core (Fig. 21) which is of Palaeocene and Cretaceous age, surrounded on all sides by a mantle of sandy marl, grey and red in colour, of Tertiary age (Fig. 22). Towards the west the anticline is faulted.

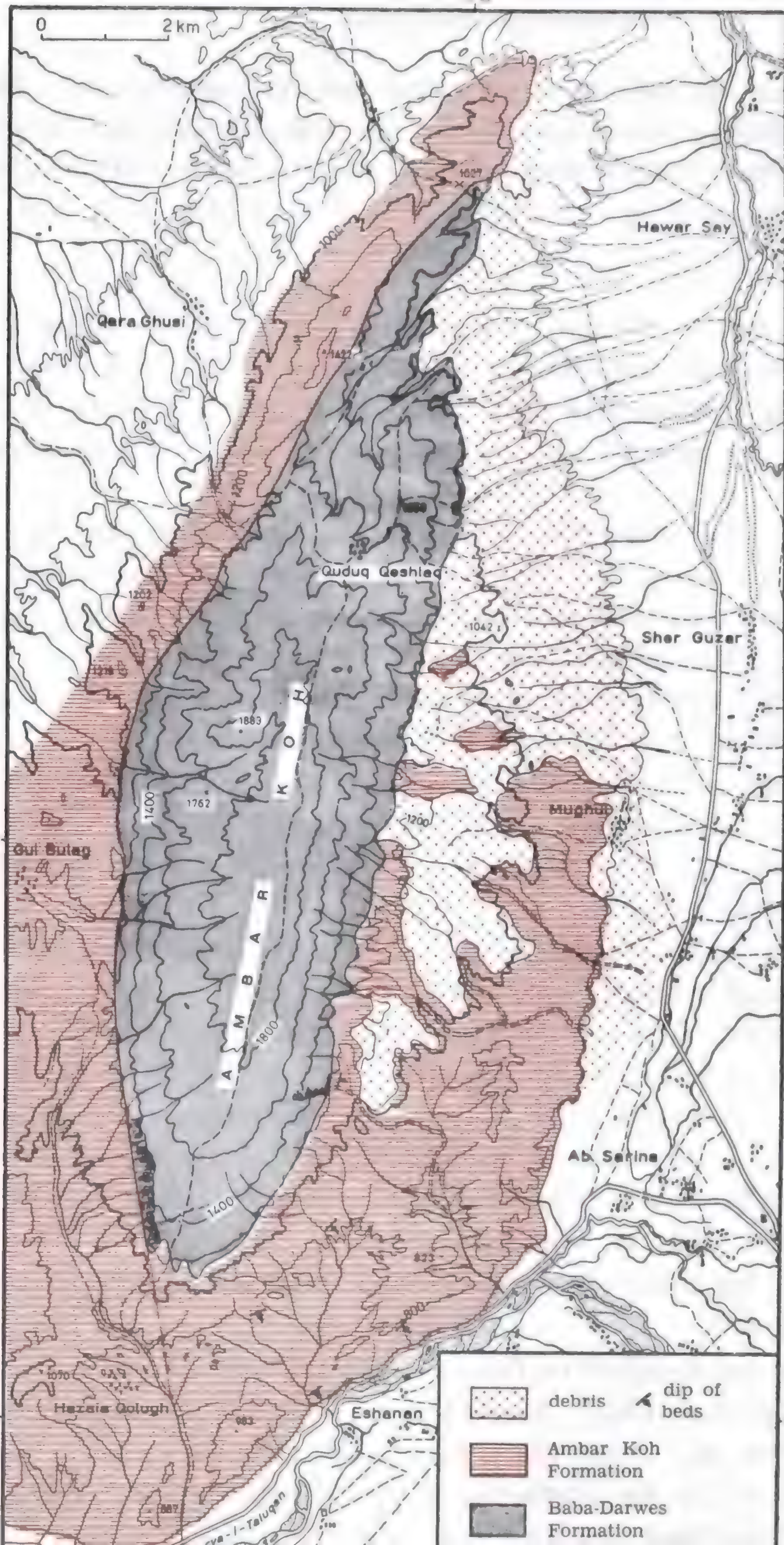

Fig. 22 - Geological sketch-map of Ambar Koh. (Red lines indicate the faults).

This mountain has only been summarily surveyed geologically. One stratigraphic section on the south-southeast side was surveyed and sampled for fossils and rocks. Other stratigraphic observations and a further collection of rocks and fossils were made on the southern side as it will be described below.

Previous Knowledge. — The first geological information on the Ambar Koh has a palaeontological character and was presented by L. R. Cox in 1938. The fossils mentioned by Cox were collected in 1936 by H. de Cizancourt and H. Vautrin and were sent to him for study. In this respect Cox wrote:
« Au Koh-i-Ambar, des échantillons, recuellis dans la partie moyenne des séries à Ostreidae, ont donné des formes qui paraissent être plus ou moins intermédiaires entre la type d'*Ostrea multicostata* et sa varieté *strictiplicata*. comme les observations de terrain semblent indiquer pour l'horizon correspondant un âge légèrement anterieur a celui des horizons précédentement en cause, il est possible que l'Yprésien soit ainsi représenté ».

No other publications appeared until 1964 when C. Hinze published a summary account of a sequence (4 horizons) studied near the village of Hazara Qolugh on the south-western side of Ambar Koh, a series almost 400 m thick.

From the new samples collected there the microfossils were determined in a preliminary way and without taking account of the Russian literature, however, no list relative to the Ambar Koh was given. On the other hand, five species of Ostracea were mentioned that is: *Gryphaea esterhazyi* Pavai, *Gryphaea cizancourti* (Cox), *Liogryphaea cocanensis* (Cox), *Ostrea longirostris* Haur., *O.* cf. *multicostata* Desh., *Cardium* cf. *porulosum* Haur., *Clamys* sp. *O. multicostata* was found also near the Cungha-i-Ulya bridge and on the southern side of Koh-i-Jawlancha.

According to this author the Grypheae came from the upper part of the section of Ambar Koh.

The same section discussed by Hinze was mentioned later with certain variations by M. Kaever (1965). Acccording to these authors in this sequence all the stages from the Upper Cretaceous to the Middle Eocene are represented, but in reality the attribution of the lithostratigraphic units identified are in part arbitrary.

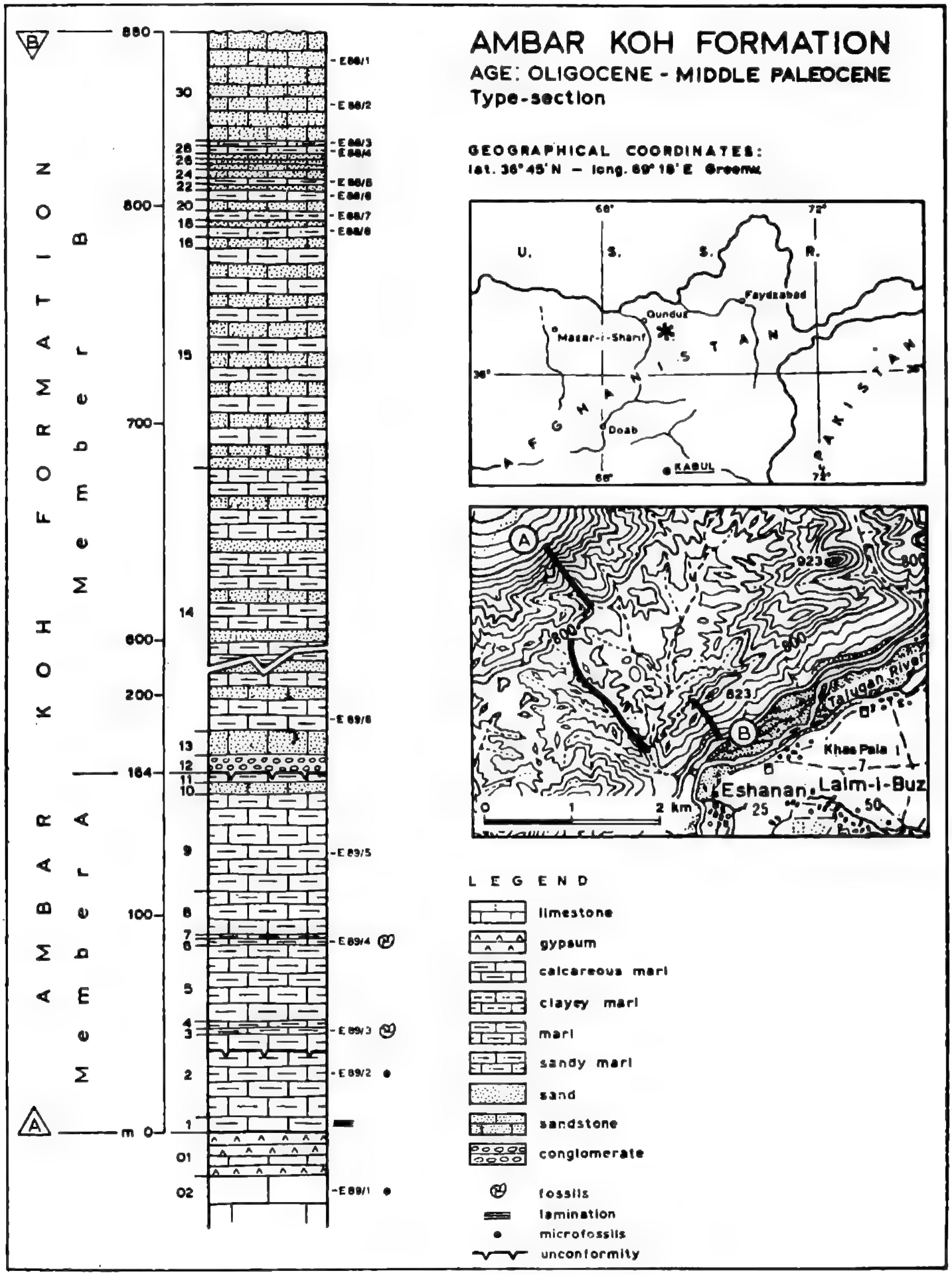

Fig. 23 - Type-section of the Ambar Formation.

O. S. Vialov, I. Nedelku & Niza dealt with the Ambar Koh sections, mainly the first author, in a report in 1966 dedicated to the rectification of certain preceding interpretations on the basis of a revision of Cox's palaeontological determinations.

Type Section. — The type section was surveyed at 36° 46′ north Lat. and 69° 18′ east Long. of Greenwich in the valley which descends on the south-southeast side of Ambar Koh and which joins the Taluqan valley in front of the village of Eshanan, 17 km west of Taluqan (Fig. 23). The beds dip towards the south-east at 40°. From Ambar Koh going down towards the Taluqan river, the lithostratigraphical sequence is as follows from top to bottom (1):

30) reddish sandstone (61 AE-88/1) with grey sandstone intercalations (61 AE-88/2). The beds dip towards the SE at 50°. Thickness 50 m;
29) light yellowish sandy marl (61 AE-88/3), 0.50 m;
28) yellowish sandy marl (61 AE-88/4), 5 m;
27) reddish sandstone, 2 m;
26) grey sandstone, 3 m;
25) grey sandstone with small pebbles, 2 m;
24) grey sandstone, 5 m;
23) grey-brown marl (61 AE-88/5), 1 m;
22) greyish sandstone, 3.50 m;
21) yellowish marl (61 AE-88/6), 3.50 m;
20) grey sandstone, 6 m;
19) grey and reddish argillaceous marl (61 AE-88/), 4 m;
18) grey sandstone, 2 m;
17) yellowish sandy marl (61 AE-88/8) with some intercalations of grey sandstone, 7.50 m;
16) grey sandstone with small pebbles, 4 m;
15) grey sandstone alternating with reddish marl, 100 m;
14) reddish marl (61 AE-88/6) with intercalations at certain horizons of sandstone and sand, grey and reddish in colour, 500 m;

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(1) See in the Palaeontological Appendix 1 the description of the microfacies. The fossils are described in the IV-2 volume of this collection (see page 16).

13) grey sandstone, 10 m;
12) grey conglomerate; the dip is to the south-east at 45°, 8 m;
11) reddish marl, 4 m;
10) reddish sandstone, 5 m;
9) reddish marl (61 AE-89/5) rich in minute detrital red and black elements, yellowish quartz, iron ore, fragments of crystalline rock and calcite grains, probably of organic origin. The microfossil content is poor and not well preserved. It consists of bryozoa and foraminifera, among which are agglutinating forms, *Cibicides* and *Globigerina* sp., 45 m;
8) grey marl 20 m;
7) grey light calcareous marl 2 m;
6) grey marl (61 AE-89/4) with fossils, including *Pterolucina pharaonis bialata* (Bellardi), *Fatina beldersaiensis romanowski* (Böhm) (Plate III, fig. 2), 2 m thick;
5) grey marl more or less calcareous, 36 m;
4) grey marl, 3 m;
3) grey marl more or less calcareous (61 AE-89/3), with fossils including *Pterolucina mokattamensis* (Oppenheim), *P. pharaonis bialata* (Bellardi), *Meretrix semisulcata* (Lamk.), *Arctica transversa* d'Archiac, *Cardium kaulanum* Cotter, 2 m;
2) light grey marl with arenaceous fragments, iron ore and pyrite. The organic content is made up of molluscan fragments, fish teeth and abundant foraminifera. The assemblage is dominated by the Lagenidae including *Robulus roemeri* (Reuss), *Robulus* sp., *Nodosaria* sp., *Lenticulina* sp., Buliminidae, *Stilostomella* sp., *Bulimina ovata* d'Orbigny, *Textularia* sp., *Eponides* sp., *Cibicides* sp., *Globorotalia ehrenbergi* Bolli and *Globigerina triloculinoides* Plummer of the Upper Palaeocene, together with *Acarinina falsospiralis* Davidson & Morozova, *Globigerina* sp. aff. *incostans* Subbotina etc., 40 m;
1) grey foliated calcareous marl, 5 m;
01) white gypsum with intercalations of grey limestone in beds 10 cm thick, 20 m;
02) maroon limestone (impure foraminiferal biosparite) (61 AE-89/1) with molluscan and echinoid fragments, abundant *Cibicides* sp. and related forms, Miliolidae, agglutinating foraminifera, Rotalidae, in thick beds etc.

The total thickness of this section is more than 900 m.

In front of the village of Eshanan, where the small valley in which this stratigraphic section was measured joins the Taluqan river, the following fossils were collected but n o t i n s i t u (61 AE-89/7):

Ostrea (*Cymbulostrea*) *multicostata* DESHYES,
Ostrea (*Turkostrea*) *cizancourti* COX,
Ostrea (*Turkostrea*) *khaudaguensis* VIALOV,
Ostrea sp. indet. VIALOV,
Ostrea (*Turkostrea*) *turkestanensis turkestanensis* ROMANOWSKY,
Ostrea (*Turkostrea*) *turkestanensis alaica* VIALOV,
Ostrea (*Turkostrea*) *turkestanensis borgalensis* VIALOV,
Liostrea (*Kokanostrea*) *kokanensis* (SOKOLOV),
Gryphaea (*Ferganea*) *sewerzowi* ROMANOWSKI
Gryphaea (*Gryphaea*) *smirnowi* ROMANOWSKI
Fatina (*Sokolowia*) *esterhazyi esterhazyi* (PAVAY, partim VIALOV),
Fatina (*Sokolowia*) *esterhazyi buhsei* GREW,
Fatina (*Fatina*) *böhmi böhmi* (VIALOV),
Fatina (*Fatina*) *beldersaiensis beldersaiensis* (GORIDZRO, partim VIALOV),
Fatina (*Fatina*) *beldersaiensis romanowskyi* BÖHM.

These fossils are certainly derived from units of the Ambar Koh section.

Certain other observations were made along a torrent course which descends along the southern side of the Ambar Koh towards the Hugi Jangal « caravanserai » and which cuts across the series of beds partly covering the ellipsoidal structure. These beds dip to the south at 40°. Fossils were collected at two different horizons, and others without any distinction of horizon (Fig. 21).

The lowest bed of the local series is a greenish marly limestone (61 AD-55/1) of which blocks were collected which had fallen from the rock walls at the head of the torrent bed (Plate III, fig. 1). The fossils collected from the blocks include *Ostrea* (*Turkostrea*) *khadaguensis* VIALOV, *Ostrea* (*Turkostrea*) *turkestanensis baissunensis* BÖHM, *Ostrea* (*Turkostrea*) *cizancourti* COX, all Lutetian forms (Alai stage). The much thicker overlying beds are composed of argillaceous marls and red and grey-green sandstone (61 AD-55) with gypsum. The fossils collected sporadically through these beds include the following species:

Fatina (*Sokolowia*) *esterhazyi esterhazyi* (Pavay, partim Vialov),
Fatina (*Sokolowia*) *esterhazyi buhsei* (Grew),
Fatina (*Fatina*) *böhmi böhmi* (Vialov),
Fatina (*Fatina*) *beldersaiensis beldersaiensis* (Goridzho, partim Vialov),
Fatina (*Fatina*) *beldersaiensis romanowskyi* Böhm.
These are forms from the Priabonian (Turkestan stage).

From the lithostratigraphical point of view this series of beds, which are relatively homogeneous, is well qualified to represent a true formation and, from the mountain where they are best exposed, they can be called the Ambar Koh Formation. At the base there are beds of limestone and gypsum of horizons 01 and 02 which form part of the underlying formation (Baba Darwes Formation) and which comprises the core of the Ambar Koh structure.

The Bluti formation must be coeval with the Ambar Koh Formation of which it represents, however, only an intermediate part (see page 86).

The top of the formation is not known because locally the highest horizons disappear under recent alluvium: probably more extensive local study would enable the top to be determined.

However it should be noted in this connection that among the fossils collected not in situ there is a species, *Gryphaea* (*Ferganea*) *sewerzowi* Romanowsky of Oligocene age, which is also present in the fossiliferous Oligocene outcrops occurring further to the west (Shiboglu Kotal) and which will be discussed below.

It is thus possible that the highest beds of this formation are of Oligocene age.

Again from the lithostratigraphical point of view the Ambar Koh Formation can be divided into two members which are termed member A and is predominately marls, in the lower part, and member B which is mainly sandstone, in the upper part.

The first comprises horizons 1-11 and is 164 m thick, the second horizons 13-30 and is 709 thick. The two members are separated from each other by a bed of conglomerate 8 m thick and perhaps by a slight unconformity.

Areal Distribution. — This formation apart from forming all the flanks of the Ambar Koh structure, also composes the mountain which rises to the

west, or rather to the north-northeast of Khan Abad. It forms the western part of Koh-i-Jawlanca, between 1292 m and 960 m north of Awlya Chasma. The same formation extends also to the north and south as far as the immediate neighbourhood of Khan Abad where it disappears under the discordant gravels of Taluqan (Fig. 16). If one follows the road from Taluqan to Khan Abad, at the height of Ab Sarina beyond the alluvial terraces, one sees towards the west the red marl beds which comprise all the heights which form the south-westerly slopes of Ambar Koh. Between Eshanan and Nagel beds become almost vertical.

Further, at the height of the village of Chin Za-i, the same red marls pass from the right hand side to the opposite side of the Taluqan valley.

From the Cugha-i-Ulya bridge as far as Khan Abad the road crosses the Khan Abad river and runs along the slopes of a series of hills composed of of the same red marl formation in beds with a moderate dip towards the south-east.

Near Khan Abad the formation disappears under the Taluqan gravel cover.

AGE. — The age of Ambar Koh Formation is fairly well documented by determinations on the fossils which were collected at various horizons. The following is a list starting from the lowest levelsof the type-section.

a) The lowest fossiliferous horizon which has provided significant species is horizon 2. It contains a fairly rich foraminiferal fauna with the zonal marker *Globorotalia ehrenbergi* BOLLI which is typical of the Middle Palaeocene. Beds 1 and 2 and the underlying limestone (gypsiferous) represent, by correlation with similar deposits in Tashkurghan, Barfaq and Ali Abad, the Middle Palaeocene and correspond to the lower horizons of the Bukhara stage of Tadzhikistan with which they also have lithological affinites.

b) Above these beds horizon 3 is encountered which has provided various macrofossils. Of these, two are Lutetian species, that is *Pterolucina mokattamensis* (OPPENHEIM) and *Meretrix semisulcata* (LAMK.). Two forms are also present in the Lutetian (Alai stage) and the Priabonian (Turkestan stage) that is *Pterolucina pharaonis pharaonis* (BELLARDI) and *Pterolucina pharaonis bialata* (BELLARDI). Of the two remaining, one is known only from the Ypresian, that is *Arctica transversa* D'ARCHIAC and the other *Car-*

dium kauleanum COTTER. It should be noted that the above mentioned species seem to represent, when grouped together, both the Lutetian (Alai stage) and the Priabonian (Turkestan stage).

At this point it should be noted that between horizon 2 (Middle Palaeocene, Bukhara stage) and 3 Lutetian — Priabonian, Alai — Turkestan stages) there is a depositional hiatus which corresponds to the Upper Palaeocene—Lower Eocene (Bukhara, major part, Susak stages) similar to what has been observed at Ali Abad, Barfaq and Tashkurghan (see Appendix 1). In the field a stratigraphical discontinuity between the two horizons has not been distinguished, but it must be aknowledged that this was not studied in detail.

As far as the association of forms the Alai stage and the Turkestan stage in horizon 3 are concerned it should be mentioned that on the southern side the fossils collected at two different horizons were distinct in terms of age. All the forms from the lower horizon, that is *Ostrea* (*Turkostrea*) *khaudaguensis* VIALOV, *Ostrea* (*Turkostrea*) *turkestanensis baissunensis* BÖHM, *Ostrea* (*Turkostrea*) *cizancourti* COX, come from the Alai stage, and all those from the higher horizon are from the Turkestan stage. It will be seen in another stratigraphical section (Tashkurghan) that there are other factor which are pertinent to this discussion.

c) Except for horizon 6 in the type-section no significant fossils were found in spite of a careful examination of numerous samples for microfossils. Only two fossils were collected from horizon 6, that is *Pterolucina pharaonis bialata* (BELLARDI) and *Fatina* (*Fatina*) *beldersaiensis romanowskii* (BÖHM), the first from the Alai and Turkestan stages, the second only from the Turkestan stage (Plate III, fig. 2).

d) Finally it must be noted again that among the fossils collected, not in place, on Ambar Koh, there is an Oligocene species *Gryphaea* (*Ferganea*) *sewerzowi* ROMANOWSKY (Sumssar stage), which is also present in beds of the same age on Shiboglu Kotal (page 136). It would thus appear that the highest horizons of the Ambar Koh Formation extend up to the Sumssar stage to which at least a part of the beds above horizon 6 must be referred. It might be said that the predominatly arenaceous member can be assigned to this stage.

In this respect it should be osserved that in his study of the same area

Hinze (1964) did not distinguish the « red continental series » of the Russian authors (J. Jl'in et al., 1947) from the overlying beds corresponding to our Kokcha Formation; he thus referred the entire complex of detrital deposits to the Oligocene—Miocene—Pliocene.

6. THE PALAEOCENE SEQUENCES OF ALI ABAD.

Introduction. — The village of Ali Abad is situated on the important arterial road from Kabul to Kunduz, some 24 km from the latter major inhabited centre on the right bank of the Baghlan river.

North of Ali Abad these hills decrease in height and cease, through which the Baghlan river winds in a narrow valley and crosses a wide alluvial plain hich continues towards Kunduz. Tre rocks which form the hills which rise to the south of Ali Abad are of particular geological interest above all because of the stratigraphy and the relative abundance of the fossils. This area is particularly favourable for stratigraphical studies because of the relatively low dips of the strata.

In spite of the fact that it was outside the area of this particular study, the summary examination of three short stratigraphic sequences, was undertaken with a view to eventual correlation with the neighbouring areas.

Unfortunately the brief time available prevented the study of a complete sequence. However it is considered useful to present the data collected.

Previous Knowledge. — Apparently the first record of the presence of Eocene fossils near Ali Abad was given by L. R. Cox (1938) who mentioned the occurrence of *Ostrea cizancourti* Cox from the Middle Eocene (Lower Lutetian), collected by H. de Cizancourt and H. Vautrin.

Subsequently Cox (1940) described a small fossil fauna collected by H. G. Schenck 10 kms south of Ali Abad, a fauna which he attributed to the Oligocene (?). The forms recorded are *Cordiopsis* cf. *incrassata* (Sowerby), *Psammotaea* cf. *fischeri* (Heb. & Renevier), *Psammotaea* sp., *Thracia* sp., *Calyptraea* sp., and *Natica* sp.

A brief note on the presence of the Eocene and Oligocene near Ali Abad was also presented by A. Desio (1960).

More complete data on the Eocene beds present south of Ali Abad were published by C. HINZE (1964) and M. KAEVER (1965). From a stratigraphical section more than 400 m thick HINZE collected 12 samples and from these numerous foraminiferal species were identified. According to KAEVER the uppermost Palaeocene, the Lower Eocene and the lowermost Middle Eocene are present in the Ali Abad sequence, but the palaeontological proof is not convincing.

The Middle Eocene is poorest in genera and species and his age determination, taking account of the four foraminiferal species doubtfully identified, is problematical because of documentary defects.

As far as the Lower Eocene is concerned the fossils listed are more numerous but the greater part are not of precise stratigraphic value. However, the microfauna seems to be of Lower Eocene—Palaeocene age, but the rare planktonic foraminiferal determinations present perplexing results. The species listed, in fact, give contradictory ages; these are *Globorotalia* cf. *membranacea* (EHRENBERG) in sample 654, *Globigerina* cf. *bulloides* D'ORBIGNY and *Globorotalia crassaformis* GALLOWAY & WISSLER in sample 652.

The first of the species cited according to modern Russian authors should indicate the Middle-Upper Palaeocene (= *G. pseudomenardii*); *Globigerina bulloides* is a living species which has not been found below the Oligocene, while *Globorotalia crassaformis* is considered characteristic of the Pliocene, according to recent research.

Finally, Russian authors use the name *G. crassaformis* to indicate a species which is diagnostic of the lower part of the Middle Eocene (1).

The small molluscan fauna from Ali Abad described by COX and doubtfully referred to the Oligocene, has been restudied by O. S. VIALOV, I. NEDELKU & P. NIZA (1966) to demonstrate that the distribution of the species in Ferghana and in the Tadzhikistan depression cannot be referred to any chronological sequence because almost all were present also in the Eocene, and they concluded that it is difficult to accept the presence of Oligocene rocks in northern Afghanistan. The same conclusions were presented in the work by DESIO (1960) where the sandy clays with gypsum and rock salt together with fossils between Jar and Ali Abad were considered to belong to the Oligocene or Miocene.

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(1) See Palaeontological Appendix 1.

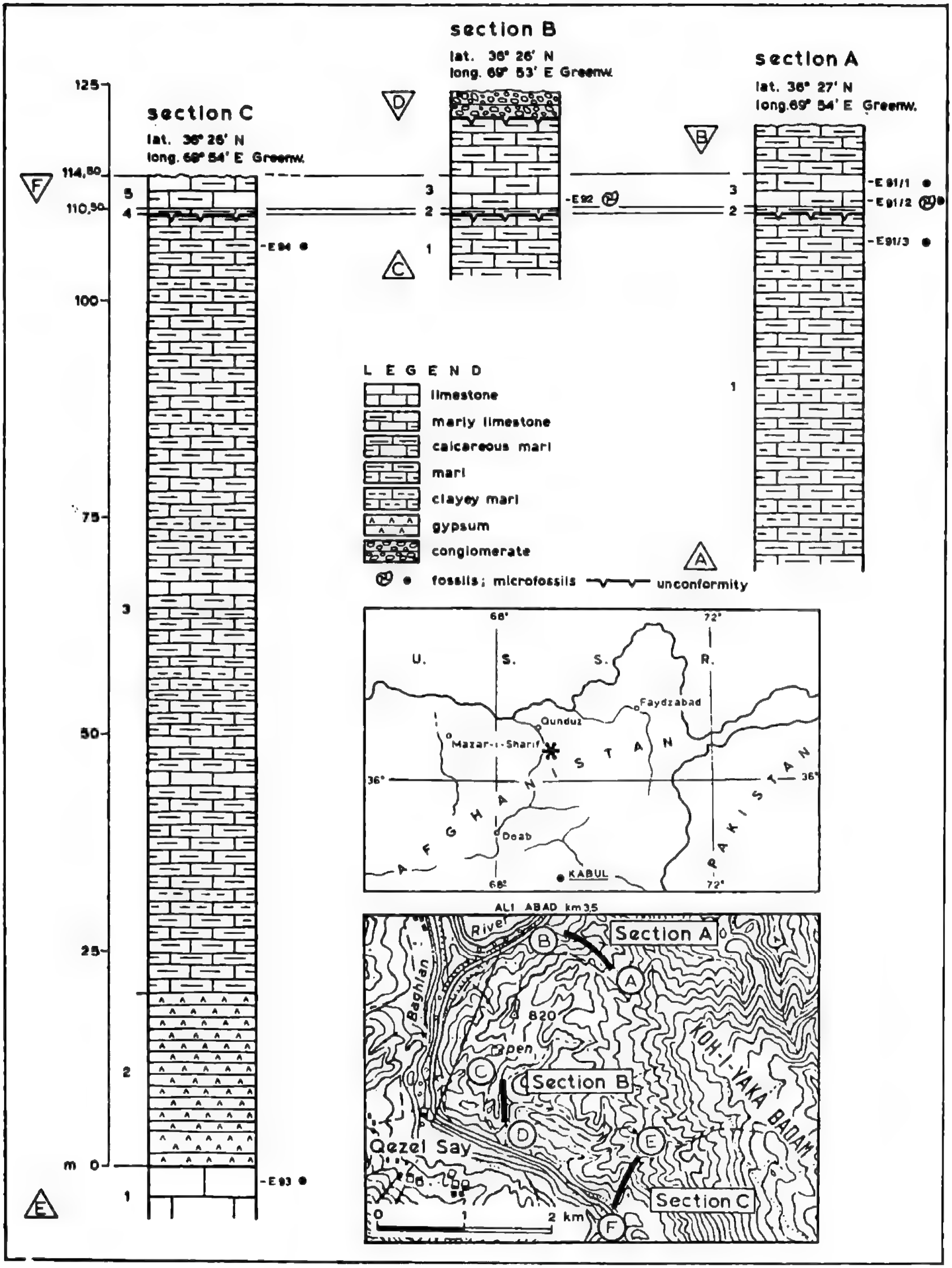

Fig. 24 - Stratigraphical sections in the Ali Abad area.

STRATIGRAPHICAL SECTION. — Three sections (A, B, C) were briefly surveyed along the road to Baghlan at 4, 8 and 10 km south of Ali Abad (Fig. 24) (2).

Section A. This section was surveyed in the small valley descending from the north-western slope of the Koh-i-Jaka (or Band-i-Kataghan), just to the east of the road, 4 km from Ali Abad. The geographical coordinates are: 69° 54′ east Long. (Greenwich) and 36° 27′ north Lat. The lithostratigraphical sequence has a thickness of about 20 m. The beds dip 20° to the north. From the top to the bottom the sequence is as follows:

4) red and grey marls, unknown thickness;
3) grey, calcareous marl (61 AE-91/1) and limestone (61 AE-91/2) with abundant clastic quartz and rare glauconite; the fossils are: ostracodes, Miliolidae, rotalids, etc., *Cardium kauleanum* COTTER and *Otsrea* (*Cymbulostrea*) *multicostata* DESHAYES, 4 m;
2) red marl, 0.5 m;
1) grey-blue marl (61 AE-91/3) with quartz grains, feldspar, pyrite, gypsum, iron minerals and abundant foraminifera, mainly Lagenidae. The genera *Robulus, Lagena, Nodosaria* (among which *N. bacillum* DEFRANCE) are present as large specimens; *Spiroplectammina, Trochammina, Bulimina, Uvigerina elongata* COLE, *Cibicides, Eponides* etc. are also present as well as ostracodes and fish teeth; planktonic foraminifera are rare, 40 m;

Other fossils were collected in the talus; they are the following: *Ostrea* (*Turkostrea*) *afghanica* VIALOV, *O.* (*Turkostrea*) *cizancourti* COX, *Liostrea* (*Kakanostrea*) *kakanensis* SOKOLOV, *Cardium halaense* D'ARCHIAC.

Section B. — This section was surveyed in the small valley descending towards the south from the hill marked 620 m, at the extreme north-western side of the Koh-i-Jaka Badam, north of the road and 8 km from Ali Abad. The geographical coordinates are: 69° 53′ east Long. and 36° 26′ north Lat. The beds dip 40° to the south-southwest. The sequence, from, top to bottom, is the following:

4) red marl with reddish conglomerate;
3) grey, marly limestone (61 AE-92) with *Ostrea* (*Cymbulostrea*) *multicosta-*

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(1) See also Paleontological Appendix 1 and 2.

ta DESH., O. (*Turkostrea*) *cizancourti* COX, O. (*Turkostrea*) *turkestanensis baissumensis* BÖHM, *Meretrix semisulcata* LAMK., *Arctica transversa* D'ARCH., *A. subathoensis* D'ARCH., *Diplodonta cycloidea* (BELLARDI), *Cardium halaense* D'ARCH., *C. cauleanum* COTTER, 4 m;

2) reddish marl, 0.5 m;

1) grey-blue marl, exposed for only a few metres.

Section C. — This stratigraphical section was surveyed on the south-western slope of the Koh-i-Jaka Badam, just to the east of the road to Baghlan and 10 km south of Ali Abad. The geographical coordinates are: 69° 54′ east Long. Greenwich and 36 26′ north Lat.

The stratigraphical sequence, diping 40° to the south, is, from top to bottom, the following:

5) grey, calcareous marl, 4 m;

4) reddish marl, 0.5 m;

3) grey-blue marl (61 AE-94) with quartz grains, iron minerals and mica cakes. The organic content consists of internal casts of foraminifera, Globigerinides, Anomalinides, Lagenidae. The marl alternates with beds of limestone and marly shale, 90 m;

2) white gypsum in beds 10-20 cm thick, 20 m;

1) light-brown limestone (biosparite) (61 AE-93) in thick beds, with foraminifera and mollusc fragments; it contains also rotalids, *Cibicides* sp. and Miliolidae.

In nearby areas specimens of *Ostrea* (*Turkostrea*) *cizancourti* Cox, were also collected.

When one compares the three stratigraphical sections surveyed near Ali Abad, it is clear that horizon 3 of section A, horizon 3 of section B, and horizon 5 of section C, consisting of grey calcareous marls, can be correlated. These marl horizons, in fact, have the same thicknesses in the three sections and overlie the same unit, 0.5 m thick, consisting of reddish marl; moreover, two of the three section (A and B) contain macro and microfossils of Middle-Upper Eocene (Alai-Turkestan stage).

The stratigraphic correlation of the three horizons is furthermore confirmed by the presence, in the three sections, of grey-blue marls in the underlying beds and, in sections A and B, of the overlying red marl (horizon 4).

A comparison between the three sections surveyed near Ali Abad and the sections of the Ambar Koh, 45 km away, enable us to establish some stratigraphic correlations.

It is at once evident that a correlation exists between horizon 6 of the Ambar Koh section and horizon 3 of Ali Abad sections A and B: in fact, these units, consisting of grey calcareous marl, contain fossils of Middle—Upper Eocene age (Alai-Turkestan) stage).

In both sections, this same horizon overlies a sequence of marl (86 m thick at the Ambar Koh-units 7, 6, 5, 4 and 3; 90.5 m thick at Ali Abad units 4 and 3), then gypsum 20 m thick (units 2), and finally brown biosparite in thick beds (units 1). These three horizons can therefore be correlated.

Finally, both in the Ambar Koh section and in sections A and B of Ali Abad, the grey calcareous marl containing Middle—Upper Eocene fossils underlies red and grey marl.

It is now important to observe that the fossils contained in the grey calcareous marl of section B (horizon 3) are the same as those in the grey marl belonging to the Bluti Formation: evidently this marl horizon of Middle—Upper Eocene age is present in all the sections, occasionally with several microfossil associations and occasionally nonfossiliferous (section C).

It is still necessary to determine whether the Ali Abad series extends up to the Oligocene. This would appear possible if account is taken that overlying the fossiliferous beds of Upper Eocene age there are other beds of red marls and conglomerates which could correlate, at least in the upper part, with the beds of member B in the Ambar Koh series. At this moment, however, valid palaeontological data are lacking and the evidence provided by Cox (1940) is not sufficient proof.

Age. The macro and microfauna present in the samples collected at the various horizons in the three sections enable a chronological classification of the surveyed sequences to be made.

a) The basal massive limestone with gypsum (horizon 1 of section C), on account of their microfaunal content (small Miliolidae) and microfacies, can be correlated with the limestones (also gypsiferous) of the basal part of the Ambar Koh section, with horizon 14 of the Barfaq section and with horizon 2-3-4 of Tashkurghan: they were dated as Middle Palaeocene.

b) The overlying thick marls (horizon 3 of section C and horizon 1 of section A), on the basis of their benthonic foraminiferal content, may be correlated with horizon 14 of the Barfaq section which can be dated as Middle Palaeocene. This same dating is confirmed by the correlation of the Barfaq marls with the marls of the Ambar Koh Formation (horizon 2).

c) Both horizons 3 of sections A and B and horizon 5 of section C (completely correlatable lithostratigraphically), provided, besides other fossils, the following macrofauna: 3 Lutetian species i.e. *Ostrea* (*Turkostrea*) *cizancourti* Cox, *O.* (*T.*) *turkestanensis baissunensis* Böhm, and *Metrix semisulcata* (Lamk.), a Priabonian species i.e. *Cardium kauleanum* Cotter and an Ypresian species i.e. *Arctica transversa* (d'Archiac). The marls, where these fossils were collected, could thus be assigned, at least in part, to the Middle-Upper Eocene and Lower Eocene.

d) As stated previously (page 127), a depositional hiatus, corresponding to the Upper Palaeocene—Lower Eocene, must occur in the Ambar Koh Formation.

At Ali Abad also the same hiatus is present: in fact, the sediments of Middle Palaeocene age (horizons 1, 2, and 3 of section C) underlie the marls of Middle—Upper (and partly) Lower Eocene.

However, while at Ambar Koh the pertinent erosional surface was not seen, it is evident in the three sections of Ali Abad (horizon 4 of section C and horizon 2 of sections A and B): such an erosional surface is represented by red marl 0.5 m thick.

This stratigraphic gap discovered at Ambar Koh, Ali Abad, Barfaq and Tashkurghan, was also mentioned in the Russian literature dealing with Tadzhikistan.

In this connection it should be pointed out that Kaever's doubts (1965) about some foraminifera of Palaeocene—Lower Eocene age at Ali Abad, are removed by the presence of the sedimentary hiatus and explained by the fact that this author was not aware of the recent studies carried out by the Russian.

e) Finally, it should be pointed out that the reddish marl and the reddish conglomerate at the top of the Ali Abad sections could be correlated with similar sediments belonging to Member B of the Ambar Koh Formation. We are now faced with the controversy concerning the pos-

sible presence of the Oligocene, that is whether or not the Ali Abad series extends upwards to include the whole or part of it.

This possibility exists if account is taken that the fossiliferous beds of Upper Eocene age are overlain by beds of red marls and conglomerates which could be correlated, at least the upper horizons, with the beds belonging to the Member B, most probably Oligocene in age, of the Ambar Koh series. Up to now, however, valid palaeontological evidence is lacking since Cox's evidence is considered insufficient (page 133).

Nevertheless, mention should be made that further to the west (Shiboglu Kotal) the Oligocene (Sumssar stage) is definitely present as will be shown in the next chapter.

OTHER REMARKS. — In the Ambar Koh region the passage beds from the Bluti formation to the Baba Darwes Formation are also clearly visible. This passage is marked by the presence of generally grey limestone, gypsum and marl. In the same area, the Bluti formation is overlain by about 700 m thickness of reddish unfossiliferous clays, marls and sandstone. These strata, which between Khanabad and Taluqan are covered by the transgressive Kokcha Formation, are possibly correlatable with the « red continental series » of Russian authors and they should represent the Oligocene and Late Eocene (in part) (= Khanabad-Sumssar stages).

The Bluti formation, because of its lithological characteristics and fossils, seems to be correlatable with the Alay and Turkestan stages of Russian authors. However, as already pointed out by DESIO (1961), the fossils of the Alay and Turkestan stages come from the same unit and the two abovementoned horizons here are not, therefore, separable.

7. PALEOGENE BEDS OF SHIBOGLU KOTAL.

Few data are available on this area located along the road between Kunduz and Tashkurghan; DESIO visited it briefly while travelling between Kunduz and Mazar-i-Sherif. Nevertheless he collected some samples and several fossils which enable us to add important data to those previously known.

The Shiboglu Kotal [1] is briefly mentioned by POPOL and TROMP (1954, page 380): « In this area isolated limestone outcrops were found in the surrounding plain containing an (Upper) Middle Eocene Oyster fauna ». In table I is added: « Upper m. Eocene (Acc. to R. G. S. HUDSON) S. 45 l.s. *Ostrea esterhazi* Pavay var. *romanowskii* Böhm ».

A short account about this locality is given in a paper by VIALOV, NEDELKU & NIZA (1966) in which it is mentioned that the presence of beds of Middle Eocene age would be confirmed by the evidence described in the previously mentioned report by POPOL and TROMP.

DESIO collected the samples at two different localities, one (E) on the eastern side at the bottom of the slope leading to the pass, the second one (W) on the opposite side to the west of the pass. As will be explained later the beds outcropping at the first locality are stratigraphically higher than those at the second locality altough the latter are, topographically, lower. At the first locality (E) red and greyish marls (61 AD-57) outcrop together with conglomerates with calcareous cement (61 AD-57') in which thick beds with well preserved Ostreae and some gasteropods are present. A. BERIZZI (1970) identified the following species which are mentioned here because of their frequency: *Amphidonte galeata galeata* (ROMANOWSKY), *A. galeata rotula* (VIALOV), *Gryphaea* (*Ferganea*) *sewerzowi* ROMANOWSKY [1]. All these specimens belong to the Middle Oligocene or, to be more precise, to the « Sumssar stage » of the Russian geologists.

At the second locality, that is on the western side of the Shiboglu Kotal, the road cuts through a series of white or greenish beds (61 AD-58) in which are contained thick beds of Ostreae and other pelecypods (61 AD-58') which are also present in great number on the road-bed. The specimens that A. BERIZZI (1970) identified are the following:

Ostrea (*Turkostrea*) *cizancourti* COX,
Ostrea (*Turkostrea*) *afghanica* VIALOV,
Ostrea (*Turkostrea*) *khaudaguensis* VIALOV,
Ostrea (*Turkostrea*) *turkestanensis baissunensis* BÖHM,
Ostrea (*Cymbulostrea*) *multicostata* DESHAYES,
Ostrea (*Flemingostrea*) *schurabica* VIALOV,

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(1) *Kotal* means *Pass.*
(1) The fossils are described in the volume IV-2 of this collection.

Fatina (Sokolowia) esterhazyi buhsei (GREW.),
Venus everesti D'ARCHIAC,
Venus cf. *gumberensis* D'ARCHIAC,
Venus sp. ind. aff. *matheroni* COQUAND,
Corbicula veneriformis (DESHAYES),
Meretrix incrassata (SOWERBY),
Meretrix aegyptiaca (MAYER-EYMAR),
Meretrix transversa (SOWERBY),
Diplodonta cycloidea (BELLARDI),
Cavilucina (Pegophysema) thebaica (ZITTEL),
Pterolucina cf. *menardi* DESHAYES.

The most significant specimens are *Ostrea (Turkostrea) cizancourti* COX, *O. (Turkostrea) afghanica* VIALOV, *O. (Turkostrea) turkestanensis baissunensis* BÖHM, and represent the Lutetian; the following, *Ostrea (Flemingostrea) schurabica* VIALOV and *Fatina (Sokolowia) esterhazyi buhsei* (GREW.), the Priabonian. The rest belong to both or spread over a wider stratigraphic interval. They belong, however, to the Alai and Turkestan stages.

8. CRETACEOUS-EOCENE SEQUENCE OF TASHKURGHAN (MAZAR-I-SHARIF).

INTRODUCTION. — From the geological point of view, the best known locality is Tashkurghan. The stratigraphic series is well exposed between Kunduz and Mazar-i-Sharif, about 4 km south of Tashkurghan village on the road leading to Haibak (Fig. 25). The road cuts through the Chaharkin-i-Mazar-i-Sharif mountain range along a very narrow and picturesque rocky gorge eroded into the Upper Cretaceous limestones; but the stratigraphic series is mostly exposed on the northern side of the mountain range where, however, the beds are repeatedly folded. On account of this the sequence of lithostratigraphic units is irregular; some units are repeated but their identification is facilitated by the relative abundance of micro- and megafossils contained in almost all the units. However, it should be pointed out that this interesting section was not investigated in such detail as the outcrops and the relative abundance of fossils deserved.

DESIO spent only one day investigating this section on the northern side of the mountain range.

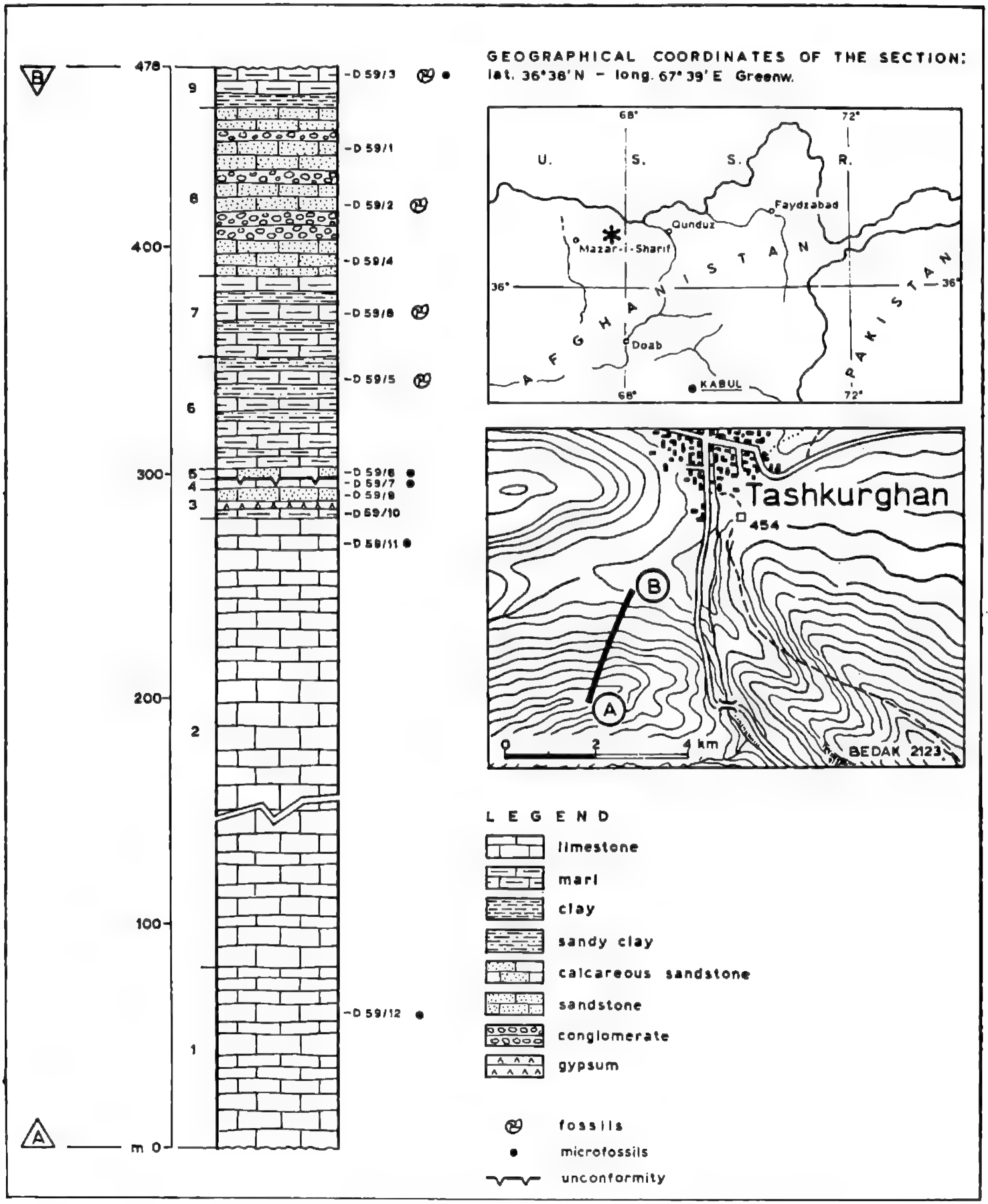

Fig. 25 - Stratigraphical sequence near Tashkurghan (Mazar-i-Sharif).

Previous Knowledge. — The first data concerning the Tashkurghan area were collected by C. L. Griesbach (1886) who recognized beds of Upper Cretaceous and Eocene age. In this connecction Griesbach (page 257) wrote: « Conformably on the northern flank of the cretaceous anticlinal, south of Tashkurghan and Balkh, I found the older tertiary clays and sandstones more or less identical with the groups as described from Mathar, and they pass here also gradually into the bright red and green clays and sandstones of the lower pliocenes ». It should be added that these beds were assigned to the Eocene on the basis of their correlation with the Mathar beds where he had found only an *Exogyra* sp. Short notes on this series were later published by Bartoux (1933) and by Vialov (1936) this latter author defined the stratigraphic position of the horizon with *Ostrea multicostata*. Popol and Tromp (1954) described the area in more detail. In the stratigraphic table attached to their report a sequence is shown which was surveyed, in the lower part, at 1 and 3 km south of Tashkurghan canyon respectively and the upper part was surveyed to the north of the canyon. In the latter section most of the Eocene and the Senonian ages should be represented, both with a marly facies. *Ostrea gigantica* Solanders is mentioned as the megafossil indicating the Lower Eocene; *O. multicostata strictiplicata* Raulin & Delbos, *O. esterhazyi* var. Roman, and *O. cizancourti* Cox indicating the Middle Eocene. The Middle Eocene beds overlie disconformably, according to these authors, the Lower Eocene while there is no sedimentary hiatus between the Lower Eocene and the Upper Cretaceous beds. Other Cretaceous stages occur beneath the Upper Cretaceous but for the present they are not described because the section surveyed by us starts with the Maastrichtian.

Among the microfossils found in the series surveyed to «the north of the canyon at Tashkurghan, west of the gorge », more or less at the location of our section and assigned to the base of the Middle Eocene, the following genera are mentioned: *Bolivina, Hopkinsina, Loxostoma, Uvigerina, Globigerina, Globigerinella, Robulus, Nonionella.* Generally the microfauna does not appear to be characteristic.

Later Cox (1938) re-examined the stratigraphical position of the *Ostreae* assigning *O. esterhazyi* to the Lutetian-Auversian, *O. multicostata strictiplicata* and *O. cizancourti* to the Lutetian, and *O. gigantica* doubtfully to the Ypresian.

In later publications by MENNESSIER (1961), SOLUM & CHEPOV (1963), VIALOV, NEDEL'KU & NIZA (1966), KAEVER (1967) etc. other stratigraphical interpretations of the Tashkurghan section were given. Particularly interesting are the reports by SOLUM & KEPOV, and by VIALOV, NEDEL'KU & NIZA. The first for the correlations between the Badkhyz section, in Tadzhikistan, and those in the Tashkurghan region of which they also show a columnar section; the second for the discussions on the stratigraphy of the various sections, including also the Tashkurghan section, based on the various species of Ostreae and referred to the stratigraphic stages created by VIALOV in the Fergana region (VIALOV, 1937). Moreover, the stratigraphy is compared with that of the Shibargan series surveyed in detail by NEDEL'KU & NIZA in northern Afghanistan, between Mazar-i-Sherif and Andkhoj, and studied palaeontologically by VIALOV.

VIALOV also discussed the wrong attribution of *Ostrea multicostata* to the Miocene collected by GRIESBACH at Tashkurghan and assigns it, as he did in 1936, to the Eocene (Alai stage). According to this author this specimen is an *Exogyra*, probably of Cretaceous age. He disputes also the attribution of *O. strictiplicata* RAUL & DELB., found at Tashkurghan later, to a variety of *O. multicostata* DESH. and interprets it as belonging to *O. turkestanensis* ROM. and var. *baissunensis* BÖHM and to *O. afghanica* VIALOV which should represent the Alai stage. The Susak stage, on the contrary, is not represented at Tashkurghan.

On the other hand *O. esterhazyi* is the *Fatina baldersaiensis romanowskyi* BÖHM belonging to the Turkestan stage and *O. gigantica* SOL. of COX, is *O. hemiglobosa* ROM.

It is not considered necessary to deal further with this matter concerning Tashkurghan because, as already stated, this region was not studied in any detail and only DESIO visited it for a short time, but nevertheless acquiring some new stratigraphic data.

STRATIGRAPHICAL SECTION. — The stratigraphic series surveyed by DESIO on the northern side of the Chakarkin-i-Mazar-i-Sharif mountain range, just to the west of the road to Haibak (Fig. 25), is, from top to bottom, the following:

9) Light-green marl and clay (61 AD-59/3) with quartz grains, gypsum lamellae, calcite and mica flakes. Among the fossils found are foraminifera

such as *Globigerina tarchanensis* SUBBOTINA & KHUTSIEVA, *Uvigerina spinicostata* CUSHMAN & JARVIS, *Nonion, Quinqueloculina, Cibicides, Virgulina*; radiolaria, ostracoda, echinoid spines, and mollusca such as *Fatina (Sokolowia) esterhazyi esterhazyi* VIALOV, *F. (Sokolowia) esterhazyi buhsei* (GREW.), *(Fatina) böhmi transita* VIALOV, *F. (Fatina) böhmi böhmi* VIALOV, *Fatina (Fatina) beldersaiensis beldersaiensis* (GORIZDRO, partim) VIALOV, *Fatina beldersaiensis romanowskyi* BÖHM, *Venus everesti* D'ARCHIAC.. Thickness: 15 m (such a thickness is perhaps exaggerated by the presence of a fold);

8) Red sandstone (61 AD-59/1, 2, 4) with quartz and calcite crystals, and lenses of conglomerate without granitic pebbles, marly clay and white, crystalline gypsum. Some *Ostrea* sp. shells are present: among them *Ostrea (Turkostrea) afghanica* VIALOV, *O. (Turkostrea) cizancourti* COX, 75 m thick;

7) Green marl and sandy clay (61 AD-59/8) with gypsum and large *Ostrea* shells belonging to *Ostrea (Turkostrea) turkestanensis borgalensis* VIALOV, *O. (Turkostrea) khaudaguensis* VIALOV, *O. (Cymbulostrea) multicostata* DESHAYES. Thickness: 35 m;

6) Green marl and sandy clay (61 AD-59/5) with little gypsum and *Ostrea (Solidostrea) hemiglobosa* ROMANOWSKY, *Gryphaea (Gryphaea) latypiga* VIALOV, *G. (Phygraea) tournali* (DONCEUX), 50 m thick;

5) Grey-yellowish, well bedded calcareous sandstone (61 AD-59/6) with quartz crystals, gypsum lamellae, mica flakes and glauconite; the organic content is represented by planktonic and benthonic foraminifera, among them: *Globigerina pseudoeocaena* SUBBOTINA, *G. falsospiralis* (DAR, & MOR.), *G.* cf. *tarchanensis* SUBBOTINA & KHUTSIEVA, *Cibicides* sp., *Rotalia beckeri* BYKOVA, *Uvigerina* sp., *Chilogümbelina trinitatensis* (CUSH. & RENZ), Miliolidae, Textularidae, *Nonion*, ostracoda, radiolaria, echinoid spines and some re-worked *Globotruncana* spp. and *Hedbergella* spp., 4 m;

4) White, clayey biosparite (61 AD-59/7) with small bryozoa agglutinating foraminifera, rare Globigerinidae, molluscan fragments, calcareous algae, 3 m;

3) Light-green to whitish marl with gypsum (61 AD-59/10); also one bed, 2 m thick, of grey sandstone (61 AD-59/9). Total thickness 16 m;

2) White and grey limestone (bio-intrasparite (61 AD-59/11) with foramini-

fera such as *Cibicides* sp., Miliolidae, agglutinating forms and bryozoa, molluscan and echinoid fragments, 200 m thick;

1) Green limestone (foraminiferal bio-intramicrosparite, 61 AD-59/12) with abundant *Siderolites*, among which *S. calcitrapoides* LAMK., containing also *Lepidorbitoides* sp., *L.* cf. *socialis* (LEYMERIE), *Orbitoides apiculata* (SCHLUMB.), *Omphalocyclus macroporus* (LAMK.); smaller foraminifera are also present: Rotalidae, agglutinating forms and rare plancktonic such as *Globotruncana stuarti* DE LAPPARENT, and molluscan fragments, calcareous algae, bryozoa etc.; 80 m;

It should be mentioned that the thicknesses as measured in the field are greatly exaggerated by tectonic dislocations; the ones shown above represent the real thickness of the series surveyed by DESIO at Tashkurghan, that is 478 m.

AGE. — The Tashkurghan section is particularly interesting because its lithostratigraphical units are chronologically defined. Starting from the bottom of the series, the palaeontological determinations of the microfossils by M. B. CITA and I. PREMOLI SILVA, and of the megafossils by C. ROSSI RONCHETTI and A. BERIZZI indicate that horizon 1 is of Maastrichtian age and this is confirmed by the assemblage of *Orbitoides, Lepidorbitoides, Siderolites*, and *Globotruncana* (see Micropalaeontological Appendix).

Horizon 2 and 4, based on their foraminiferal content, are referred to the Middle Palaeocene (Bukhara stage).

Horizon 5, can be safely referred to the upper part of the Lower Eocene, based on its microfauna.

Another horizon which can be dated on its palaeontological content, represented this age by the *Ostreae*, is the 6 which contain significant forms belonging to the Ypresian (Susak stage): *Ostrea* (*Solidostrea*) *hemiglobosa* ROMANOWSKY and *Gryphaea* (*Gryphaea*) *latypiga* VIALOV. Horizon 7 is characterised by the presence of very large shells of *Ostreae* (some shell measure up to half a metre) belonging to forms of Lutetian age (Alai stage) such as *Ostrea* (*Turkostrea*) *turkestanensis borgalensis* VIALOV and *O.* (*Turkostrea*) *khaudaguensis* VIALOV or both to the Lutetian and the Ypresian such as *O.* (*Cymbulostrea*) *multicostata* DESH. (Susak and Alai stages).

The fauna of horizon 8 also belongs to the Lutetian, still represented mainly by the *Ostreae*.

The next horizon (9) is, palaeontologically, the best documented as it contains both micro and megafossils suitable for determination and belonging to the Middle—Upper Eocene. Almost all the *Ostreae,* represented only by the gen. *Fatina* belong to this age; among the microfossils present are *Globorotalia rotundimarginata* and *Globigerina officinalis.*

Therefore, in the Tashkurghan section there is a stratigraphic hiatus from Middle Palaeocene (horizon 4) to the upper part of the Lower Eocene (horizon 5). This depositional break, mentioned also in Russian publications, had already been observed by us at Barfaq, Ambar Koh, and especially at Ali Abad, where the relative erosional surface was also found (seen also further to the west, in the Badkyz series, by SOLUM & CHEPOV (1963).

It must be pointed out, however, that while at Tashkurghan the depositional break includes the Upper Palaeocene and the lower part of the Lower Eocene, at Ambar Koh and Ali Abad it is more extensive and includes all of the Lower Eocene.

However, at Tashkurghan, the fossils assemblages characteristic of the Susak, Alai and Turkestan stages are in fact present in normal succession while in Ambar Koh and Ali Abad sections fossils breaks and condensations are present within the above mentioned units.

9. THE PALAEONTOLOGICAL MARKERS FROM THE STRATIGRAPHICAL SEQUENCES WEST OF FAYDZABAD.

In this chapter we shall discuss the relationships between the various formations indicating the principal markers on which the correlations are based (see Fig. 26).

The oldest fossiliferous sedimentary formation examined is the Karkar Formation (illustrated on page 95 etc.) which is Upper Jurassic with the highest horizon arriving in the Middle Jurassic. It is the marine formation which unconformably overlies the continental beds with coal measures which is the Upper Saighan Formation of Middle Jurassic age.

Above the Karkar Formation a marker bed (1) is present, which is characterised by a microfacies comprising oosparite to biosparites rich in molluscan debris, in the lower part of horizon 32 (sample 61 AP-178/34) of the Karkar section (« Green Beds ») and in the Gazestan Formation, in

horizon 2 (61 AE-87/5 b) of the Farkhar section at Archa Kotal (61 AE-77/1) and in the lower part of horizon II (61 AD-48/18 a) of the Qara Tut section. The age of this unit cannot be determined directly because of the lack of diagnostic microfossils. It is probably Lower Cretaceous and certainly not younger than Cenomanian, since it underlies the *Cuneolina - Dicyclina* bearing horizon in the Farkhar section.

Higher in the same Karkhar section there is another marker horizon (2) composed of sandy oosparite with Miliolidae (in the upper part of horizon 32, samples 61 AP-178/35 and 36), which from the similarity of the microfacies is perfectly correlatable with horizon 1 (sample 61 AE-95/1) of the B section at Pull-i-Khumri and with horizon 13 (61 AE-97/7) of the A section of Pull-i-Khumri; this concerns an horizon in the « Green Beds » which is also correlated with the top of the Gazestan Formation (the upper part of horizon 11 in the Qara Tut section; (61 AD-48/18 b) immediately under the Baba Darwes Formation.

The age of this horizon cannot be determined directly either it is probably Lower Cretaceous (Albian) and certainly not younger than Cenomanian, since it underlies the *Cuneolina - Dicyclina* bearing unit in the Baba Darwes — Qara Tut section.

Still higher in the Pull-i-Khumri B section an important marker bed (3) is found from horizon 16-17 (61 AE-95/13, 13 bis) characterised by the presence of *Cuneolina* and *Dicyclina*. This horizon is found also in the Baba Darwes Formation: in horizons 3, 4, 5, and 6 of the Baba Darwes section (61 AD-30/2,-3,-4/10), in horizon « d » (61 AD-34/1) of Mohammad Aba section, and horizon 2 (61 AE-87/12) of the Karkar section. The age of this horizon is certainly Upper Cretaceous and may be referred to the Cenomanian and possibly also, at least in part, to the Turonian. This chronological attribution is in agreement with to megafossil fauna collected from the same beds.

As stated on page 113, at Pull-i-Khumri the basal horizon of section A represents the start of the Albian-Cenomanian sedimentary transgression on to the crystalline basement, while the highest bed of section B contains calcareous algae and *Inoceramus*. This horizon with *Inoceramus* was first indicated in the type section of the Pull-i-Khumri Limestone (Desio, 1960) and referred to the Turonian. The close correlation is confirmed by the similarity of the microfacies between horizons 16-17 of the B section and horizon

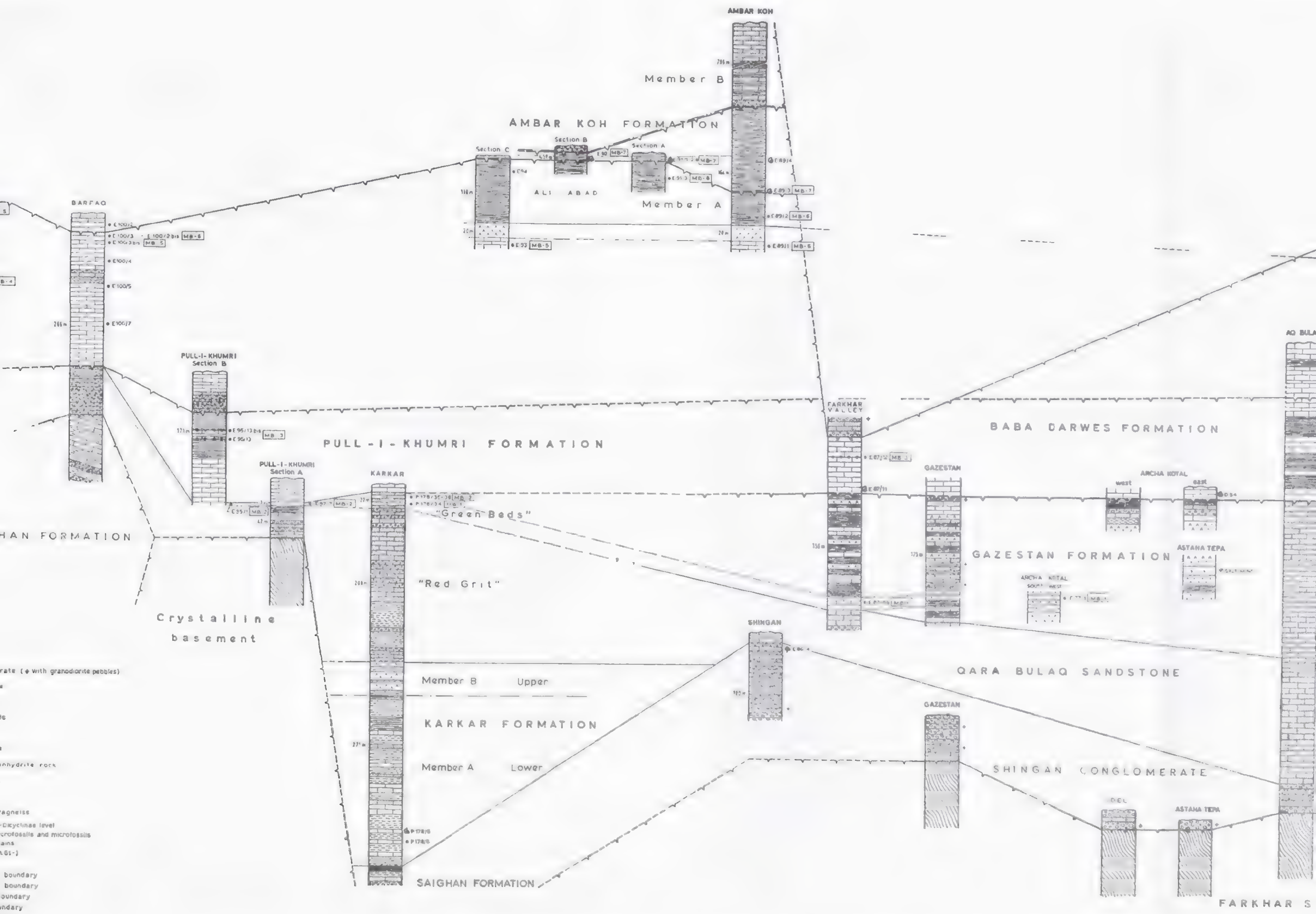

Fig. 26 - Stratigraphical correlation of the formations from Central Badakhshan (west of Faydzabad) and Kataghan

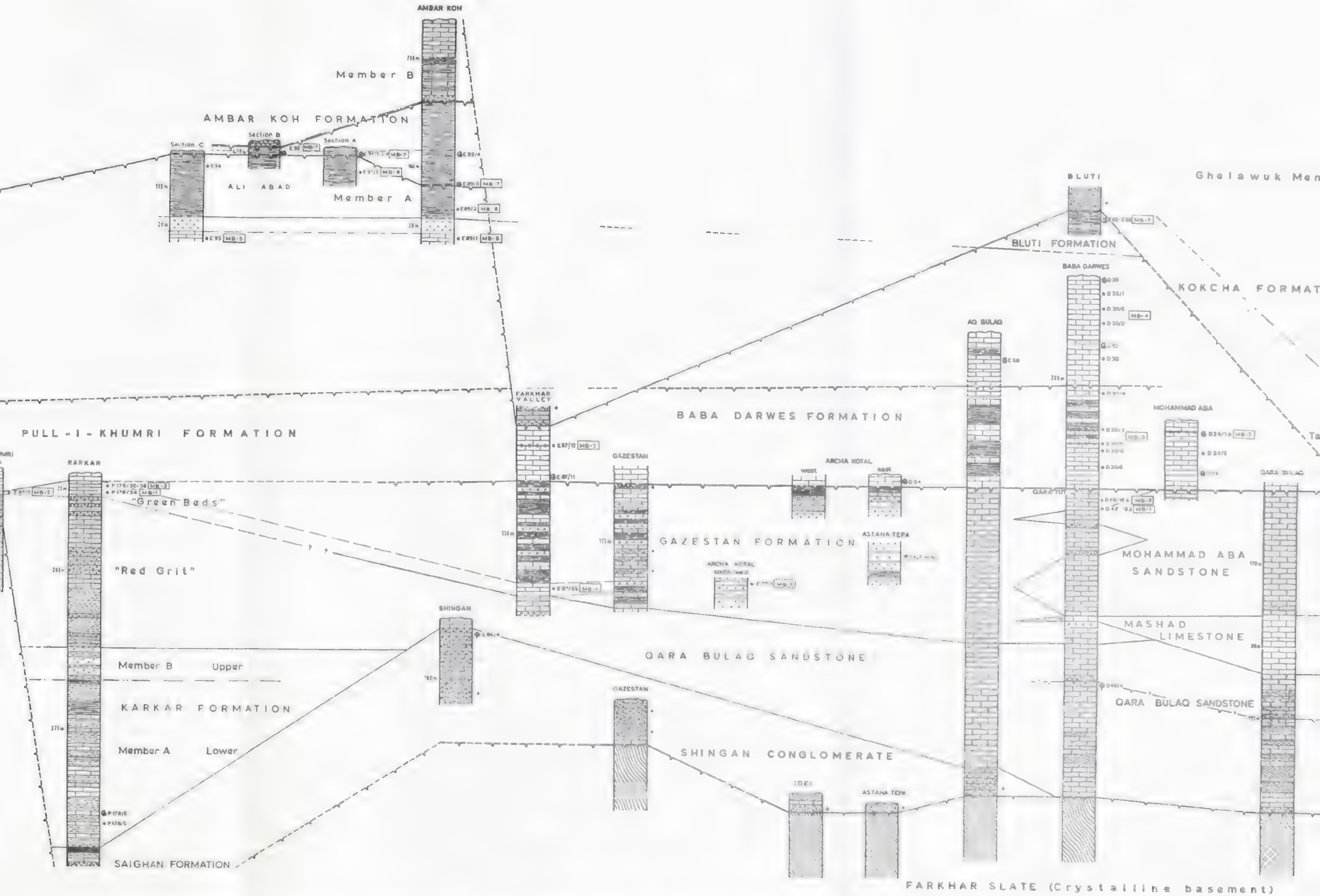

Fig. 26 - Stratigraphical correlation of the formations from Central Badakhshan (west of Faydzabad) and Kataghan

12 of the 1960 type section consisting of limestones with *Cuneolina* and *Dicyclina*. Thus, if the data are assembled for the section at Karkar and Pull-i-Khumri there is a sequence of beds which extend from the highest beds of the Saighan Formation to the top of the Pull-i-Khumri calcarenite, with a total thickness of 678.30 m, from the Middle Jurassic to the Turonian inclusive.

Further, as already seen, the Pull-i-Khumri and the Baba Darwes formations are easily correlatable because of the *Cuneolina-Dicyclina* bearing horizon, and it can be said that above, a sequence is known which comprise the Upper Cretaceous including the Maastrichtian.
In fact, horizons 9 and 10 of the Baba Darwes section (61 AD-30/3 and 5) contain *Orbitoides media* (D'ARCHIAC), *Orbitocyclina minima* (DOUVILLE) as well as *Siderolites calcitrapoides* LAMK.: the age of this assemblage is certainly Maastrichtian. This marker bed (4) has also been recognised in the Chenar-i-Gunjeshkhan pass (61 AD-35/1) and at horizon I (61 AD-59/12) in the Tashkurghan section.

Apart from this the depositional hiatus recognised between horizons 6 and 7 of the Baba Darwes section, that is between the Cenomanian—Turonian and the Maastrichtian, is confirmed at Pull-i-Khumri by the presence of conglomerates at horizons 19-20-21 in the B section.

Between the Pull-i-Khumri section and the section at Baba Darwes, which are 160 km apart, the facies variations are naturally frequent (as can be seen in fig. 26) and the crystalline basement outcrops at different horizons. In the Baba Darwes Formation, for example, the crystalline basement appears about 500 m below the *Cuneolina - Dicyclina* bearing bed: and this sequence comprises clastic and evaporitic deposits (ranging in age from the Middle Jurassic to the Lower Cretaceous—Cenomanian) of the Qara Bulaq Sandstone, the Mashad Limestone, the Mohammad Aba sandstone and the Gazestan Formation. At Pull-i-Khumri, on the other hand, the crystalline basement appears about 140 m below the *Cuneolina - Dicyclina* bearing level; this thickness being made up of clastic and evaporitic deposits of Lower Cretaceous—Cenomanian age; (« Red Grit » and « Green Beds »).

The horizons 13 (61 AE-100/3 bis) of the Barfaq section, 2 and 4 (61 AD-59/11 and 7) of the Tashkurghan section, 1 (61 AE-93) of the Ali Abad section C, and 02 (61AE-89/1) of the Ambar Koh section, may be correlated

on their similar microfacies which is characterised by intrabiosparite rich in small miliolid and rotalid foraminifera. The age of this microfacies (5) cannot be directly defined because of the lack of diagnostic fossils. However, it can be defined indirectly as Middle Palaeocene since it underlies a marker bed 6 which indicates Middle Palaeocene (which will be described below) and also because it overlies the Maastrichtian marker horizon that is unit 1 of the Tashkurghan section.

As discussed above, marker bed 6 is present in the Barfaq section (horizon 14: sample 61 AE-100/3), in the Ambar Koh section (horizon 2: 61 AE-89/2) and in the Ali Abad section A (horizon 1: 61 AE-91/3). This marker is characterised by its planktonic foraminiferal content and also on the relative stratigraphic position of the horizons, since they all overlie the miliolid bearing limestone. At Barfaq and Ambar Koh *Globorotalia ehrenbergi* is indicative of a Middle Palaeocene age (Bukhara stage). Correlation with the Ali Abad horizon is less precise due to the poor planktonic foraminiferal faunas. The benthonic assemblage however is very similar to the one found at Barfaq which suggests that they may be approximately coeval.

The last marker horizon (7) is present in horizon 3 of the Ali Abad A section (61 AE-91/2), in horizon 3 of the Ali Abad B section (61 AE-92), in horizons 3-6 in the Ambar Koh section (61 AE-89/3 and 4) and also in the Bluti formation (61 AE-65 and 66). At Ambar Koh megafossil faunas which indicate a Middle Eocene age (Alai stage) are present but reworked, in association with uppermost Middle Eocene (Turkestan stage) faunas; the associated microfaunas are, unfortunately, chronologically insignificant.

Since the underlying horizon 2 of the Ambar Koh section is (as discussed above) a marker bed of Middle Palaeocene age, evidently between the two marker horizons, there must be a depositional hiatus corresponding to the Upper Palaeocene—Lower Eocene interval. An analogous situation is seen at Ali Abad where, above the marls of the Middle Palaeocene (horizon 1 in section A) calcareous marls are found with macrofossils of the Upper—Middle, and perhaps at least in part of the Lower Eocene (horizon 3, sections A and B). Here, the depositional break corresponding to the Upper Palaeocene—Lower Eocene is clearly seen as an erosional surface represented by red marl 0.50 m thick (horizon 2, sections A and B).

Also, in the Bluti formation a similar situation to that seen in the Ambar Koh and Ali Abad must be present: as a result of the cover, however, mask-

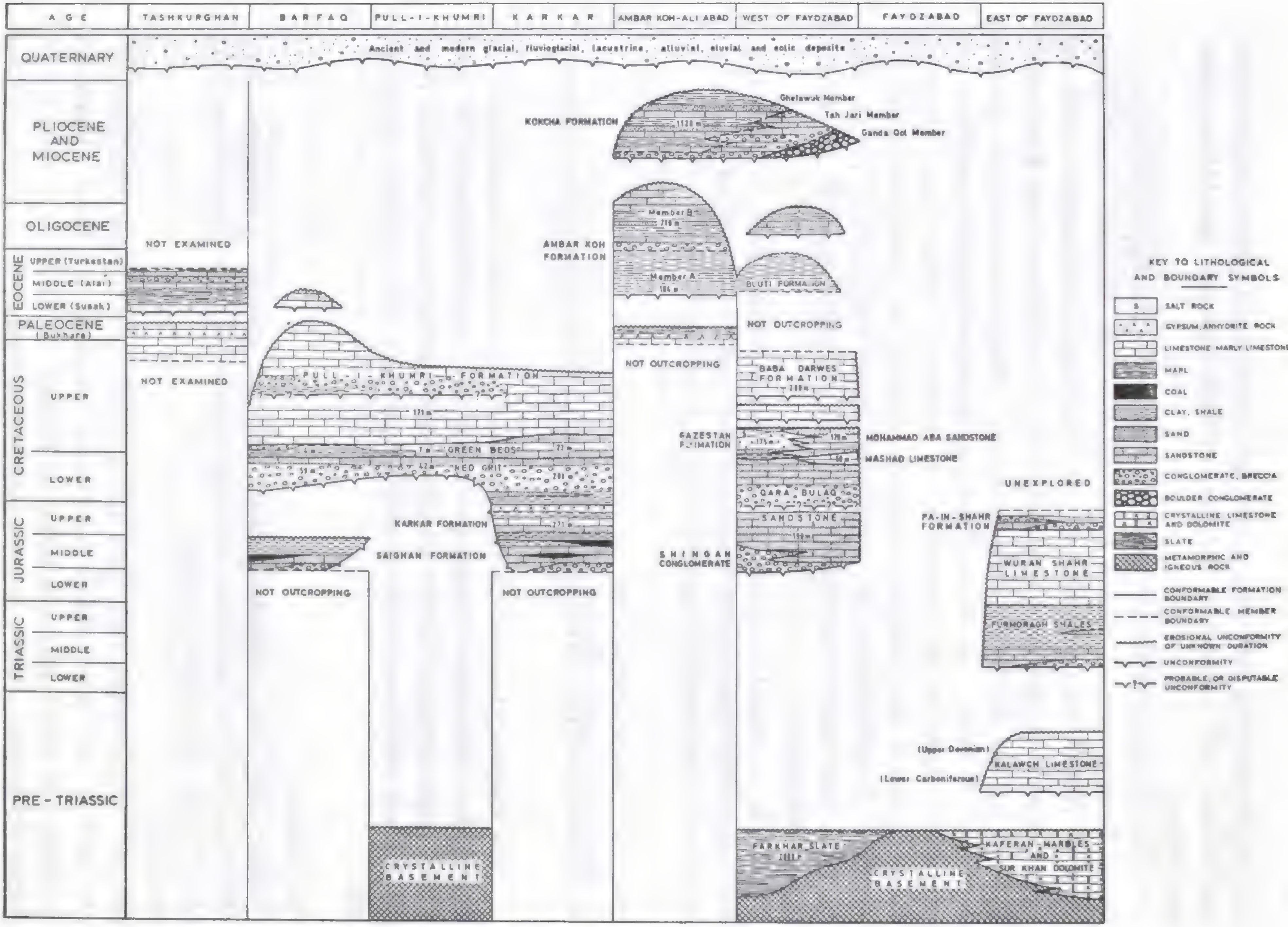

Fig. 27 - Age and relationship of sedimentary rock-units from Tashkurghan to Eastern Badakhshan.

ing the surrounding outcrops it was only possible to observe a calcareous marl horizon with megafossils of Upper—Middle Eocene age (Alai—Turkestan stages).

This depositional hiatus which corresponds to the Upper Palaeocene — Lower Eocene interval studied at Ambar Koh and Ali Abad is also observable at Tashkurghan and Barfaq. At Tashkurghan it comprise only the Upper Palaeocene and the lower part of the Lower Eocene, and it is present between horizon 4 (Middle Palaeocene age) and horizon 5 (upper part of the Lower Eocene). As far as Barfaq is concerned the data available are less precise: however the presence of an erosional surface was observed which separates the overlying sediments possibly of post-Palaeocene age (horizons 15 and 16) from the underlying marker bed (horizon 14) of Middle Palaeocene age. The depositional break at Barfaq comprise at least the Upper Palaeocene.

Finally, it should be recorded that this depositional hiatus is reported in the Russian literature and that the erosional surface was defined further to the west in the Badkya series by SOLUM & CHEPOV (1963).

10. SUMMARY OF THE STRATIGRAPHICAL SEQUENCE WEST OF FAYDZABAD.

The following is a summary of the main lithological characteristics of the various sedimentary formations which have been described in the preceding pages arranged in chronological order starting from the oldest (Fig. 27). Against each name are indicated the symbols used on the geological map.

PRE-TRIASSIC.

Farkhar Slate (Fs): epimetamorphic black and greenish arenaceous slates with basal layers of sandstone and conglomerate (without granodiorite pebbles). More than 2150 m thick.

JURASSIC.

Shingan Conglomerate (Sf): grey and greenish conglomerate with granodiorite pebbles and interbedded fine-grained micaceous sandstone. Maximum thickness 100 m, Middle and Lower(?) Jurassic.

Karkar Formation. (KKf): is composed of two members,

A. Calcareous-arenaceous-argillaceous member with mega and microfossils (marine facies). 216 m thick.

B. Clayey-marly member with anhydrite beds, 55 m thick. Middle (upper stages) and Upper Jurassic.

JURASSIC—CRETACEOUS.

Qara Bulaq Sandstone (Qf): reddish and greenish fine quartzose sandstone, siltstone with some interbedded quartz conglomerate. 190 m thick. Middle (and Upper?) Jurassic and Lower Cretaceous.

CRETACEOUS.

Gazestan Formation (Gf) red, green and grey conglomerate, sandstone, shale, clay and fossiliferous limestone with gypsum and rock-salt in an alternating sequence. Thickness from 150 to 400 m. Lower Cretaceous (upper stage) — Cenomanian (?).

Mashad Limestone (Ml) well bedded grey limestone 80 m thick wedging laterally into the Mohammad Aba Sandstone and Gazestan Formation. Lower Cretaceous — Cenomanian (?).

Mohammad Aba Sandstone (Ms) reddish and dark green quartz feldspathic sandstone 150 m thick. There is gradation laterally into the Gazestan Formation Lower Cretaceous — Cenomanian (?).

CENOMANIAN.

Pull-i-Khumri Limestone (Pck): greenish, light brown and yellow calcarenite and limestone, sometimes nodular with interbedded, green, gypsiferous marl and sanstone. Micro and megafossils present. Thickness 225 m. Cenomanian — Turonian and Senonian (in part).

CRETACEOUS—EOCENE.

Baba Darwes Formation (BDf): grey, brown and red very fossiliferous limestone, weathering often yellowish, alternating with red and brown marl 200-300 m thick. Micro and megafossils present belonging to the Cenomanian, Turonian, Maastrichtian and perhaps Palaeocene. Age: Cretaceous (from Albian (?) — Cenomanian to Maastrichtian) and possibly Palaeocene.

EOCENE.

Bluti formation (Bf): grey marl and fossiliferous (mostly *Ostrea*) limestone. Middle and Upper Eocene (Alai-Turkestan stages).

EOCENE AND OLIGOCENE.

Ambar Koh Formation (AKf): grey, red and yellow marl and sandstone with micro and megafossils; the A member (lower) is mainly marly, the upper B member is predominantly arenaceous. Total thickness over 900 m. Middle Palaeocene — Middle and Upper Eocene, probably Oligocene (Bukhara, Alai-Turkestan, ? Summsar stages).

NEOGENE.

Kokcha Formation (Kf): thick-bedded conglomerate interbedded with mainly greyish sandstone and marl with some marine and lacustrine fossils. It is divided into three members: *Tah Jari Member* (Kf) made up mainly of sandstone and conglomerate, *Ghelawuk Member* (Kf′) composed of marl and sandstone, *Ganda Qol Member* (Kf″) conglomerate. Thickness more the 1100 m. Age: Neogene.

In order to complete the survey of the stratigraphy in the mapped region the following sequences must be added:

1) Cretaceous—Eocene sequence of Tashkurghan,
2) Cretaceous—Palaeocene sequence of Barfaq (Doab),
3) Palaeocene sequences of Ali Abad,
4) Palaeocene beds at Shiboglu Kotal.

All these rock units are more less richly fossiliferous and enable clarification and completion of certain gaps in our knowledge of the formations largely as a result of markers which are common to them.

In Table 2 (at the end of the volume) the various formations and stratigraphical sequences have been grouped together with the relative age of each, for the area to the west of Faydzabad. The table shows the coeval formations and the chronological succession, but also the gaps which should be emphasized.

11. COMMENTS ON THE STRATIGRAPHY OF THE SEDIMENTARY FORMATIONS WEST OF FAYDZABAD.

The Table 2 and the stratigraphical summary reproduced in the fig. 27 require some comments. We begin from the oldest formations of the area west of Faydzabad, but in the fig. 27 there are also included the oldest formations outcropping to these east of Faydzabad in order to compare the reciprocal stratigraphical position of the formations of both areas.

PRE-TRIASSIC. — If the oldest sedimentary formation, which is metamorphosed is examined, it becomes clear that the Farkhar Slate is not always continuous in vertical section. As previously stated, in the region studied the Farkhar Slate is directly covered by more recent trangressive formations, thus between its deposition and the Shinghan Conglomerate or the Saighan Formation which are of Jurassic age, there is a great gap in sedimentation. This break, in the area studied, represents a long phase of uplift and emergence, but to the south other formations are known, in part continental, in part marine, which may fill this break.

This subject will be discussed below.

JURASSIC. — It must be noted that apart from the Farkhar Slate in the area mapped the oldest sedimentary formations is the Shinghan Conglomerate which is of Middle Jurassic and perhaps the upper part of the Lower Jurassic (Lias). It reflects a continental or epicontinental phase which is also represented by the Qara Bulaq Sandstone.

Only with the Albian—Cenomanian is there the start of a marine cycle of sedimentation. It is true that at Karkar a marine horizon exists which is well documented with Upper Jurassic fossils, but this is only a local episode, a marginal expansion of brief duration when the sea extended northwards.

CRETACEOUS. — The Albian—Cenomanian (?) trangression in the region surveyed established the start of the Upper Cretaceous marine cycle which developed over the whole area studied and was maintained, even though some breaks may be present, at least up to the Cenozoic.

To the Lower Cretaceous (Albian—Cenomanian ?) have been attributed three homotaxial formations (Mohammad Aba Sandstone, Mashad Limestone and Gazestan Formation) which pass laterally into one another. However the Cenomanian is represented by fossiliferous rocks both in the Baba Darwes Formation and in the Barfaq sequence (beds with *Cuneolina* and *Dicyclina*) which are stratigraphically more extensive higher in the sequence than the previous formations. In the Baba Darwes Formation above the Cenomanian and Turonian horizons there are other fossiliferous horizons which confirm the presence of the Maastrichtian (beds with *Lepidorbitoides*, *Siderolites* and *Exogyra overwegi* VON BUCH). However, in the strata between these and the preceding beds there is a sedimentary discontinuity, which is found at Pull-i-Khumri in the Surkhab valley, which comprises part of the Turonian and the Senonian.

Fossiliferous Maastrichtian rocks outcrop at both Baba Darwes and Tashkurghan, where the stratigraphical sequence continues upwards into the Middle—Upper Eocene (Turkestan—Alai stages). The passage from the Maastrichtian to the Palaeocene must be present to the north of the saddle of Chenar-i-Gunjeshkan, and in the passage beds between the Baba Darwes and the Bluti formations which have not yet been explored in detail. That there is continuity of sedimentation between the Cretaceous and the Eocene seems however proved indirectly by the presence in the area surveyed of beds of both Maastrichtian and Palaeocene age.

PALAEOCENE AND EOCENE. — The Palaeocene has been identified palaeontologically at Ambar Koh, Ali Abad, Barfaq and Tashkurghan and in the last two localities the beds rest directly on Maastrichtian strata without any apparent interruption in the sedimentation. However, as we have noted above, at Tashkurghan the fossiliferous series continues upwards into the upper part of the Lower Eocene and the Middle—Upper Eocene and the same continuity is found at Ali Abad also. At Ambar Koh the presence of the Middle Palaeocene (Middle Bukhara) is well documented palaeontologically together with the Middle and Upper Eocene (Alai—Turkestan stages). At Ali Abad also there is proof of the existence of Middle Palaeocene (which is the top of the section). In these last two localities the Upper Palaeocene and Lower Eocene are missing; there is, in fact, a sedimentary gap which corresponds to these two intervals, a gap which at Tashkurghan is less extensive vertically, being limited to the Upper Palaeocene and to the lower part of the Lower Eocene. As far as Barfaq is concerned there is evidence of only Middle Palaeocene and post-Palaeocene sediments, not better identified and also an erosional surface was observed immediately above the Middle Palaeocene strata.

OLIGOCENE. — The stratigraphical series is less clear higher in the sequence. There are only two localities in which Oligocene fossils were found, that is the locality east of Shiboglu Kotal and Ambar Koh. At the first locality the megafossil fauna (*Ostrea* spp.) indicates the presence of Middle Oligocene in a series of coarse-grained clastic beds; at the second locality the only palaeontological evidence is represented by one fossil species (*Gryphaea sewerzowi* ROMANOWSKI) which was found at the previous locality also. It should be noted moreover that at Ambar Koh the top of the Upper

Eocene is marked by a stratigraphical break. There are no indications of the presence of the Oligocene in the area east of Ambar Koh.

NEOGENE. — There was an interruption in sedimentation between the end of the Oligocene and the deposition of the Kokcha Formation. The latter has been assigned to the Neogene. Nowhere has continuity of sedimentation with the underlying beds been found. The dating of the Kokcha Formation is only indirect because the scarse fossils collected have not provided any satisfactory determinations. The fact that it covers a series of red beds in the neighbourhood of Ambar Koh, which with a certain hesitation have been referred to the Oligocene, suggests that the Kokcha Formation is Neogene.

These are some of the comments which arise from an examination of the table 2 and what has been said about the geological characteristics of the formations and stratigraphical sequences described. Now the relationship between the formations described above and those of the same age in surrounding areas can be discussed.

12. SOME COMPARISONS OF THE STRATIGRAPHY TO THE WEST OF FAYDZABAD WITH THAT OF THE NEIGHBOURING REGIONS.

In order to have a good basis for comparison between the sedimentary formations outcropping to the west of Faydzabad (Central Badakhshan) and the neighbouring regions, it is necessary to take into account their tectonic relationships.

It has already been demonstrated that the stratigraphy of the sedimentary formation in the area to the east of Faydzabad can on the whole be correlated with that of Central Pamir (page 41). It is known that between the two sedimentary areas located to the east and to the west of Faydzabad there is a wide belt of metamorphic and igneous rocks forming an anticlinal structure, cut on both sides by deep faults, which can be correlated with the tectonic zone of Northern Pamir. According to the interpretation given by DESIO (1965), the western Badakhshan and the Kataghan are therefore on the southern continuation of a tectonic zone outside the structures of the real Pamir and mostly related to the structures of Darwas and of the Upper

Amu Darya depression, in Tadzhikistan, of which they representet the southern continuation.

It is therefore in such regions that the correlations with the sedimentary formations outcropping in the western part of Central Badakhshan and in Kataghan must primarily be looked for.

It is convenient at this point to review the formations described in this volume beginning with the oldest. The Farkhar Formation, forming the base of the sedimentary rocks which overlie it with an angular unconformity, will be omitted.

It is already known (page 40) that the Jurassic formations outcropping in the Karkar region and those of Dashtidzhum in the western rim of Badakhshan can be correlated. This correlation can be extended to the overlying clastic deposits (« Red Grit ») of Lower Cretaceous age.

The Middle and Upper Jurassic are, however, also represented in Tadzhikistan and particularly on the southern slopes of the Hissar range (J. Jl'in, et al., 1947). Regarding the Middle Jurassic there is a coarse, clastic, continental facies, similar to that of the underlying beds — also containing, however, finer-grained, thinner, coal-bearing sediments — which could represent our Shingan Conglomerate and part of the Qara Bulaq Sandstone. In the same region lithotypes comparable with those of the Karkar Formation are also present. Lower in the sequence, in fact, there is a predominantly calcareous stratigraphical unit containing intercalations of bituminous shale, marl, sandstone and conglomerate of Callovian—Oxfordian age which can be correlated with the lower member of the Karkar Formation. Above there occurs the evaporitic formation of Haurdan, of Kimmeridgian—Tithonian age, which corresponds to the upper member of the Karkar Formation present in various parts of the Upper Amu Darya Depression.

It is not necessary to dwell on the Cretaceous—Eocene formations because a description of the palaeontological relationships between them and those of Tadzhikistan is included in Appendix A. It is necessary to mention here that in the area investigated and in the remaining part of northern Afghanistan, those coarse, clastic deposits known as the « Red Grit » overlying the Karkar Formation are referred to the Lower Cretaceous. Weippert (1968) considers the « Red Grit » a facies and not a formation and modifies the original interpretation (Griesbach). The Qara Bulaq Sand-

stone has the characteristics of a formation and also partly displays the « facies » of « Red Grit », that is a red deltaic deposit.

The eastern part of the Upper Amu Darya Depression also contains reddish, deltaic, clastic deposits (shales and rarer conglomerates) similar to the « Red Grit »; in the western part, marine and lagoonal deposits are intercalated with the continental deposits.

S. N. SIMAKOVA assigns a Valanginian—Lower Hauterivian age to the above mentioned red horizon which is well exposed between the Vakhsh and Iliak rivers. The same age also could be assigned to the Qara Bulaq Sandstone, or to a part of it.

In the same area, to the north of the Amu Darya, there is an overlying gypsiferous horizon containing some fossils (*Exogyra*) assigned to the Upper Hauterivian — Aptian which could be correlated with the Gazestan Formation overlying the Qara Bulaq Sandstone.

The Albian is also present in the same region and is mostly represented by red sandstones, occasionally containing remnants of carbonized plants and some intercalations of fossiliferous, calcareous beds. In the area investigated there are many elements which contribute to identify this stage to which WEIPPERT (1968) assigned the lower parts of the Pull-i-Khumri series without valid evidence.

In the region investigated, predominantly calcareous, Upper Cretaceous formations unconformably overlie the older ones. To the north of the Amu Darya they are averlain by a thick marine sequence, consisting of interbedded shales, sandstones and richly fossiliferous limestones. The typical sequence is still considered to be that outcropping on the south-western slopes of the Gissar which B. A. BORNEMAN (1940) divided into numerous stratigraphical units impossible to establish in the region investigated.

It is not necessary, however, to dwell further on this problem because the relationships between the previous sequence and the Upper Cretaceous and Paleogene formations of Tadzhikistan are discussed on the basis of palaeontological data — which have the greatest validity — in Appendix A.1.

Concluding, it can be stated that although a large variety of lithostratigraphic units characterise the Cretaceous—Paleogene stratigraphy of the Upper Amu Darya Depression, it is still possible to recognize a real continuity, but not always an identity, between the formations outcropping on the op-

posite sides of the Amu Darya river, which is revealed by their rich fossil faunas; this large river, in fact, does not mark any geological boundary.

Regarding the Paleogene, it can be stated that the same subdivisions of the stratigraphical series adopted for Tadzhikistan and the neighbouring regions by O. S. VIALOV are also valid in the region studied.

Regarding this, reference should be made to the two palaeontological appendices and the text. The diagrams of figg. 26 and 27 show the relationships between the stratigraphy of Kataghan and neighbouring regions. A short comment will now be made regarding the continental formations unconformably overlying those mentioned above: the Kokcha Formation and the Taluqan gravels. The two members of the former are comparable with the Polizak suite and the Kurteka Formation respectively of Pliocene age, and with part of the Miocene of Tadzhikistan and Darvaz. The latter is described in the chapter dealing with the Pleistocene.

The above discussion helps to demonstrate that the Kataghan was part of the sedimentary basin of the Upper Amu Darya Depression, and represented a part of its southern, neritic and coastal belt.

B. METAMORPHIC FORMATIONS

1. INTRODUCTION.

The metamorphic rocks also have been grouped into formations, to which local names have been assigned, as is the usual practice in the case of the sedimentary rocks.

The metamorphic formations of Central Badakhshan are derived mainly from the action of regional metamorphism on sedimentary rocks among which different facies are represented. The deepest facies is represented by three types of gneiss, that is the Faydzabad Gneiss, Tarang Gneiss and Kurkhu Gneiss. These latter two have also been affected by the action of anatexis and metasomatism.

The rocks of the medium stage have been grouped into five formations:

Rabat Gneiss, Qara Mughul Gneiss, Halqa Jar Amphibolite, Kaferan Marble, Sur Khan limestone. The Kalawch limestone has low-stage metamorphic characteristics but not sufficiently pronunced as to obscure the fossils. For this reason it has been included among the sedimentary formations together with the Wuran Shar limestone, which is also fossiliferous. As far as the black slates are concerned, as we have said previously in connection with the Furmoragh shales (page 28), under this generic name there are perhaps more formations, not all affected by the same grade or type of metamorphism.

Among the metamorphic formations the most common and widespread lithotypes are without doubt gneiss, among which five different formations have been distinguished. These are followed in their distribution by the amphibolites and then the calcareous formations. Among these we have recognized two formations, which because of their pronunced metamorphic grade have not been considered suitable for inclusion in the section on the sedimentary rocks.

The metamorphic formations which will be described in the following page are eight in number and are as follows:

1. Faydzabad Gneiss (Fg)
2. Rabat Gneiss (Rg)
   2a. East Rabat Gneiss
   2b. West Rabat Gneiss
3. Qara Mughul Gneiss (Qg)
4. Halqa Jar Amphibolite (Ha)
5. Kurkhu Gneiss (Kg)
6. Tarang Gneiss (Tg)
7. Black Slates (bs)
8. Kaferan Marble (Km)
9. Sur Khan Limestone (skl)

To these eight must be added a ninth represented by black slates, but these have been discussed together with the fossiliferous Furmoragh shales in the chapter devoted to the sedimentary formations (page 28).

These listed are not all of the metamorphic formations of the region east of Faydzabad. Near the eastern limit of the area, around Lake Shiwa and outside the area of the geological map, still other types of metamor-

phic rocks outcrop, as well as part of those listed above; rocks which will be described in the chapters dedicated in particular to the area around Lake Shiwa, Zebak and in the Wakhan valley.

2. DESCRIPTION OF THE FORMATIONS.

2.1. Faydzabad Gneiss.

General Features. — Faydzabad Gneiss forms one of the deepest metamorphic cores in Badakhshan. It crops out east of Faydzabad as a dome-shaped anticline deeply crossed by the Kokcha river.

The main lithological types are biotite-garnet-sillimanite migmatitic gneisses with kinzigitic composition. The upper levels are more massive with heterogeneous grain; they grade into augen gneiss in which the large garnet porphyroblasts commoly form lenses and beds. Everywhere, but mainly in the upper part, intercalations of marble, calcphyre and amphibolite are present.

Near the contact between the carbonatic rocks are injection zones with calcphyre and quartz-feldspar beds. At the contact between the sialic beds and the amphibolites are present amphibolite-gneiss recalling a tonalite composition. In the lowest part, besides the sialic injection bed to bed, there are real filonian granite bodies that are generally concordant. The visible total thickness is over 2000 m.

Field Observations. — Upstream from Faydzabad the Kokcha valley is deeply enclosed by a thick migmatic series, that, at first sight, shows an interesting variety of petrographical types.

The symmetric correspondence of the western contacts of the migmatitic mass round a central well differentiated zone, allows us to consider the Faydzabad Gneiss as a much compressed dome forming a very deep core in the metamorphic complex of Central Badakhshan. The dome-shaped structure is evident in the northern part, from Faydzabad as far as Pular, where the migmatites show the greatest extension. Along Kokcha valley, on the

other hand, there is a much stretched anticline overturned eastwards, that quickly dips southwards under its gneissic cover.

The beautiful outcroppings revealed by the erosion of Kokcha, mainly in its right bank, show also at macroscopic scale the migmatitic nature of the unit. The most distinctive feature is the layering in levels of different lithological composition, thickly intercalated and with marked stratiform structures that give the sequence a sedimentary appearance (Plate V fig. 1). In fact the better preserved paleosomatic relics are calcareous levels and beds transformed into calcphyres that, in spite of their thinness, can be followed for many kilometres. The gneissic rock forming the greatest part of the migmatitic complex has an intense and repeated intercalation of beds with different mineralogic composition, among which calcphyres are inserted with concordant layering. The intercalation of mafic and sialic zones is very evident, and the sialic zones grade into granite- or pegmatite-looking types. The mafic zones are formed both by very biotitic gneiss and by amphibolite beds that have the same horizontal continuity than the calcphyre and are often joined to them.

In the central part of Kokcha outcrops, near the village of Khanaqa, migmatitic biotite-garnet gneisses with sillimanite, with alternating mafic and sialic beds, the last with feldspathic eyes, lenses and lenticles (61 AP-36) prevail.

500 m west of the village, a zone of about 100 m of brown and hazel-brown calcphyres, saccharoid-loocking, rich in diopside, scapolite, hornblende, and titanite, with quartz and feldspar beds, in which potash-feldspar prevails, inteposes. Round the village, in different parts, sialic lenticular beds, some hundred metres long, in the gneisses have rather granitoid or pegmatitic composition and the gneisses contacting them become very sialic, augen and coarse-grained, with sinuous and thin biotite beds (61 AP-39). In other parts the contact forms a thin zone of enrichment in biotite and garnet, lain in fine-grained beds in which small lenses and quartz-feldspar bands are inserted (61 AP-40).

The biotite-garnet gneisses with sillimanite continue northwards as far as Khanaqa, always joined with granite-pegmatite injections, with calcphyre layers and some long amphibolite stripes.

The most important lithological features of the upper Faydzabad Gneiss are upstream Kokcha valley, after Khanaqa: they are migmatitic

gneiss with two micas. Unlike the ones just mentioned they have fine, slightly schistous, zoned grain; the feldspathic eyes are numerous, but they are regularly placed and have small dimentions (61 AP-45). But upstream there exist, less frequently, coarse biotite-garnet augen gneisses, forming narrow and repeated stripes bound to the calcphyres layers, showing the most gradual mingling with them. In the fusion zones migmatitic amphibole-biotite zoned gneiss appear; they are fine-grained, with irregular and discontinuos sialic, sometimes augen, beds, in a grey-green bottom mass (61 AP-41). Sometimes they are migmatitic gneiss particularly rich in iso-oriented garnet eyes (61 AP-42). Amphibolite stripes of various thickness are joined to calcphyres, and their bottle-green colour gives the mountains sides great chromatic relief. Some metres long near the contact, calcphyres have more crystalline structure and seem particularly rich in scapolite, edenbergite, pystachite and titanite (61 AP-43). Amphibolite have fine and massive grain, with some sialic lenses (61 AP-44).

This calcphyres and amphibolites zone continues from the Kokcha valley through the north-eastern margin of Faydzabad Gneiss as far as the village of Pular with a variable thickness of 100 to 500 m. The same happens along the south-western margin between the towns of Faydzabad and Gazan. In all these peripheral parts and in the widest dome-shaped crest of the gneiss NE of Faydzabad, the migmatitic garnetiferous gneiss with two micas, with marked schistose texture prevail, and sometimes they shows relics of mostly muscovitized sillimanite (61 AP-107).

As it is not possible to see a complete stratigraphical section of Faydzabad Gneiss, we shall describe the results of the crossing of the whole formation from east to west, that is from the Sum Darrah valley to the town of Faydzabad. The described sequence contains the more or less symmetrical repetition of all the terms forming the two parallel strongly stretched sides of the Faydzabad anticline.

We observed the sequence as follows:

a) Thin biotite-garnet paragneiss (Rabat Gneiss);

b) crystalline limestone, 5 m;

c) amphibolites and biotite-amphibole schists, 28 m;

d) crystalline limestone and calcphyre, tightly joined to amphibolite bands, 40 m;

e) biotite-garnet migmatitic augen gneiss, 20 m;
f) bands of crystalline limestone, calcphyre and amphibolite, 55 m;
g) migmatitic augen gneiss with biotite, garnet and sillimanite with some pegmatitic veins, 100 m;
h) bands of crystalline limestone, calcphyre and amphibolite, 60 m;
i) migmatic augen gneiss with biotite, garnet and sillimanite, 80 m;
k) massive microgranular amphibolite, 40 m;
l) migmatitic augen gneiss with biotite, garnet and sillimanite, 70 m;
m) paragneiss, 3 m, (61 AE-28);
n) amphibolic gneiss, 2 m, (61 AE-30);
o) very plagioclasic amphibolite (61 AE-30) and massive amphibolite (61 AE-31), 40 m;
p) migmatitic augen gneiss with biotite, garnet and sillimanite with intercalations of crystalline limestone and calcphyre, 120 m;
q) migmatitic augen gneiss very rich in garnet containing amphibolite lenses, 10 m;
r) migmatitic augen gneiss very garnetiferous with biotite and sillimanite, with intercalations of calcphyre and amphibolite at intervals of about 50 m, 700 m;
s) migmatitic gneiss with biotite, garnet and sillimanite with amphibolite bands and pegmatite and quartz veins, 300 m;
t) migmatitic banded augen gneiss with biotite, garnet and sillimanite with a few intercalations of calcphyre and amphibolite, 300 m;
u) very garnetiferous migmatitic gneiss with pegmatitic injections both conformable and unconformable, 500 m;
v) migmatitic augen gneiss with biotite, garnet and sillimanite, 300 m;
w) migmatitic augen gneiss with biotite, garnet and sometimes sillimanite, with intercalations of marble and calcphyre levels and lenses up to 20 m thick, 800 m;
x) very garnetiferous migmatitic augen gneiss, 100 m;
y) amphibolite with pegmatite veins, 60 m;
z) fine biotite paragneiss (Qara Mughul Gneiss).

Petrographical Features. — The outstanding petrographical characteristic in Faydzabad Gneiss is the strong feldspathization joined to abun-

dant metablastesis of biotite, garnet and sillimanite. The facies is similar to the Kurkhu Gneiss from which it mostly differs in the presence of important calcphyre and amphibolite intercalations, and granite, aplite and pegmatite dykes. In the gneissic types we notice a rather high recrystallization degree of paleosoma, that, in the most preserved zones, appears as a granoblastic contexture of oligoclase-andesine, quartz and biotite in iso-oriented scattered lamellae. As the feldspathic or quartzous-feldspathic beds and lenses thicken, the structure becomes more heterogeneous and biotite increases in fresh tabular patches with marked pleochroism, light yellow and red-brown coloured, joined in diablastic aggregates or in curled sheaves along which garnetiferous idioblasts and sheaf-shaped sillimanite aggregates are scattered. At the same time there is a basification of plagioclase that reaches an average andesinic composition (An_{35-37}) always in small granules of the same dimention. More seldom we find microgranoblastic types with quartz and potash-feldspar, poor in mica with alternating beds of different granulometry.

The feldspathic contribution generally happens with the growth of plagioclase eyes, with varying composition about that of paleosoma or slightly more calcic up to andesinic An_{40-42} and, in smaller quantities and not everiwhere, with potash-feldspar eyes of late crystallization if compared with the preceding one. In the types with plagioclase neosoma there is a concomitant introduction of quartz, also in great quantities, that differs from the more or less cataclastic one of the gneiss paleosoma.

Also a great amount of quartz remobilized and recrystallized in optically unitary lenses and stripes, tightly joined to the metablastic biotite-sillimanite-garnet bands belongs to this second generation.

The plagioclase eyes present uniform composition, with considerable polysintetic geminations with albite, carlsbad and pericline; as a rarity some manebach-ala twins were found. They have the shape of prismatic crystals with round edges, the major axes of which generally have trends unconformable to those of the schistosity planes even if they lay in them, wrapped in neoincreased biotite or microgranoblastic quartz borders. The potash-feldspar eyes, on the other hand, are present as isolated prismatic crystals, free from metablastic rim and of bigger dimentions that the plagioclase. In comparison with the plagioclase they later recrystallize.

In the sialic gneisses poor in mica (muscovite) there are only eyes of pot-

ash-feldspar partially produced by the recrystallization and reunion of orthose crystals present in the paleosoma, together with the limited remobilization of quartz in conformable stripes. To these gneisses are often joined bands of carbonatic rocks transformed into calcphyres, at the contact with which, fine textures develop in bands and stripes, where the gneissic portions or the just quartzous-feldspathic ones come into evidence.

All the carbonatic rocks have hornfels, where, near calcite recrystallized in spathic specimens, we can observe crystals of diopside, hornblende, edenbergite, scapolite and titanite in different proportions. Generally these components are grouped in beds and stripes made up of the following associations: diopside-hornblende-titanite, edenbergite-titanite with late hornblende. In the types rich in quartz instead of calcite there is anortite to which are joined biotite laminae that are scattered or joined in lepidoblastic sheaves; anorite and quartz form a granoblastic ground-mass not different from the above described calcphyre. To these components hornblende and scapolite crystals can be associated at the sialic bands contact.

The sialic parts generally have two different aspects: as beds with granoblastic heterogeneous structure, the central zone of which is made up of orthose crystals and the marginal ones of quartz; as discontinuous quartz lenses that include crystals abnormally increased with scapolite and hornblende or, less often with pyroxene and containing potash-feldspar eyes.

The amphibolite associated to the calcphyre bands can be grouped in two different types: amphibolite with labradoritic plagioclase with additional quartz grading into amphibole-biotite gneiss; amphibolite with anortitic plagioclase, poor in quartz, sometimes with diopside. The first ones distinguish themselves by the lineated texture given by the parallel orientation of the amphibolic prisms, orientation that grades into the schistose one in the amphibole-biotite types and by the interstitial quartz models itself. Plagioclase has an average correspondence to labradorite An_{54-64}

In the second type, the rock takes fine granoblastic quite cornubianitic structure, because of the simultaneous increase of hornblende and plagioclase. The latter has anoritic composition up to 98% An. Sometimes there are diopside porphyroblasts and plently of titanite crystals.

Petrogenetical Considerations. — The upper boundary of Faydzabad Gneiss corresponds to the first appearance of sillimanite; such a fact causes

a clear separation of facies noticeable on the ground too. In fact, with the presence of sillimanite there is a degree of regional metamorphism such to reach the field of anatexis and of the mobilisation of granitic melts.

We have already seen that the feldspathization and granitic injection phenomena are characteristic of Faydzabad Gneiss, now it must be noticed that the intensity of these phenomena symmetrically decreases from the core to the peripheral parts of the dome-shaped kinzigitic aggregate. On the roof of the aggregate, that is in the amphibolite and in the biotite paragneiss, the feldspathization abruptly stops; while the injections of granitic and pegmatitic spindles, that have greater mobility and autonomy, persist in a very attenuated way. This means that Faydzabad Gneiss is not contaminated by magmatic process of close plutons, but it forms a mobilization centre of granitic materials that has undeniable petrographic and structural evidence. The perimagmatic influence of the close circumscribed plutonic centres, as that of Abu Abdal, are tightly limited at the periphery of the pluton and, with convergence phenomena, they show their separation from the regional metamorphic evolution of the enclosing rocks.

Faydzabad Gneiss that developed themselves, as we saw, under the isograde of sillimanite, have typical mineral associations of almandine-amphibolite facies and of sillimanite-almandine sub-facies.

The greatest part of the formation shows pelitic associations characterized by the presence of quartz-sillimanite-garnet-plagioclase and biotite. In some pelitic schists with muscovite, mica tends to be substituted by potash feldspar.

The carbonatic associations present in the intercalations of marble and calcphyre are interesting, mainly for the convergence phenomena with facies of contact metamorphism. The most diffused associations are: calcite-scapolite, diopside-hornblende-titanite, edenbengite-titanite, anortite, hornblende, biotite and quartz. The fabrics are mainly markedly cornubianitic. The described associations are clearly of a transitional type to hornblende hornfels facies, characteristic of contact belts, and developed in a lower depth than that of almandine-amphibolite facies, according with Fyfe, Turner & Verhoogen (1958), and others. As for the amphibolite present in Faydzabad Gneiss its sedimentary origin seems to be sure, because of the close lying bound with the above described rocks with pelitic and calcar-

eous affinity. Other characteristics strengthening such hypothesis are: the thin, intensely zoned texture of amphibolite, the frequent orientation of hornblende crystals; the appearance of schistose and well-foliated texture; the presence of quartz.

Two are the characteristic mineralogic associations: hornblende-plagioclase-quartz, and hornblende-anortite (diopside). They can be explained with the presence of intercalations of marls or dolomitic marls and basic tufs in the pelitic-calcareous series that originated Faydzabad Gneiss. Sometimes we can speack of metasomatic substitution of carbonatic layers as well, because of the frequent gradual transitions among marble, calcphyre and amphibolite; and also because of some calcareous relics found in the amphibolite.

2.2. Rabat Gneiss.

General Features. — The name of the formation comes from the village of Rabat, lying on the right side of the Kokcha valley, upstream from Faydzabad.

Previously we enclosed the fine-grained biotite-garnet gneisses outcropping in the Kokcha and Sum Darrah valleys, to the west, and in the upper Kurkhu valley, to the east, within the so-called Rabat Gneiss formation (Desio, Martina Pasquaré, 1964). Nevertheless the different stratigraphic and structural positions of the gneisses in the west and east areas require a separation in two different units which are to be called *West Rabat Gneiss* and *East Rabat Gneiss*. The lithological differences are the following:

a) The *West Rabat Gneiss* is made up of fine-grained biotite paragneiss containing garnet and sillimanite, alternating inferiorly with marbles and calcphyres;

b) The *East Rabat Gneiss* is a biotitite-garnet paragneiss grading into migmatitic veined gneiss locally amphibolic and often rich of sillimanite. In the last gneissic sequence numerous intecalations of marbles are enclosed.

The assemblage of marble layers can originate lenticular horizons as thick as a hundred metres (1).

Field Observations. — Surveying the right side of the Kokcha valley, before the village of Rabat, we observe that the passage to Faydzabad Gneiss is extremely gradual and characterized by the interposition of biotite tabular gneiss, biotite-garnet gneiss with sillimanite (61 AP-46) and migmatitic augen gneiss.

South of Rabat the transition zone reaches a thickness of over 500 m, in which a conventional medium limit was stated.

Another point where the observation of this formation is easy is the valley of Khas, left tributary of the Kokcha river, flowing near Jurm. The narrow sides of the valley are excavated in a strongly stretched series of thin zoned, fine, biotitic paragneisses that are grey or grey-green coloured with calcitic-chloritic veins (61 AP-96, -99) and with marble and calcphyre bands frequent in the lowest part of series mainly. Marbles appear in massive levels, with coarse grain and saccharoid fracture, spotted by iron minerals nests (61 AP-101).

Calcphyres are tightly mingled to biotitic paragneisses, that, at the contact, have hornblende enrichments until they grade into amphibolic gneisses alternating in beds to the calcphyres themselves. These ones appear in the outcropping as long yellow or green-grey coloured bands, with very heterogeneous texture.

We notice typical calcphyre wit scapolite (61 AP-100) but also bands lacking in calcite, with scapolite, actinolite, diopside and titanite (61 AP-97).

In the gneiss the most important variation appearing in the lowest part of the series is the outcropping of garnet together with the acquisition of augen structure recalling the passage types to Faydzabad Gneiss round Rabat. Locally there is the passage to bands of migmatitic biotitic-garnetiferous banded augen gneiss with sillimanite, that are regularly zoned, with sialic beds with amigdalar expansions in a biotitic very diffused matrix (61 AP-98).

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(1) In the Geological Map of Central Badakhshan enclosed in the present volume, the two types of gneisses are not distinguished with particular colours. Nevertheless the outcrops to the east of Baharak meridian are to be referred to the East Rabat Gneiss, those to the west of it to the West Rabat Gneiss.

The same mixing of biotitic paragneiss, marble and calcphyre goes on northwards along the Koh-i-Surkh-Koh ridge as far as the Shahran basin. Beyond it there is a gneissic series, lacking in carbonatic relics and crossed in concordance by the intrusion of Abu Abdal granite in the central part, with peripheral contamination bands. These bands are well placed in the basin east of the Shahran village where the gneiss is clearly crossed by pegmatitic granite veins up to 1 m thick. At the contact, about 120 m thick, there is a dioritic-gabbroid mass, with irregularly oriented texture, correspondent to a migmatitic biotite-amphibole gneiss (61 AP-105). In this mass there are beds with indefinite borders of biotitic gneiss, that were enriched with feldspathic eyes (61 AP-106).

Near Sar-i-Hauwidz, calcschistose bands, enriched with contact minerals, mainly flogopite (61 AP-159), appear among gneiss and marble. From here, going upwards to Kotal Dar-Khan, there are very thick injections bed to bed, of granitic and pegmatitic material inserting into zones of great lamination of the rock, where zones of very variable composition, as biotite augen gneiss, amphibole gneiss, cornubianite with pyroxene, scapolite, amphibole and titanite (61 AP-161) alternate at a very short distance.

North of Kokcha, the gneisses go on with a thick lining up of tectonic flakes, some of which are made up of Mesozoic and Palaeozoic limestone. In the Kotal-i-Kaferan zone, besides these mechanical contacts, they can be surely seen stratigraphical contacts given by an abrupt superimposition of limestone, transformed into saccharoid marble, to biotitic, fine-grained paragneiss. Marble forms long bastions with walls falling perpendicularly, often folded forming thin synclines, resting in scanty gneissic slopes.

In the same zone, east of the Kotal-i-Kaferan, there is a long contact front between Rabat Gneiss and Halqa Jar Amphibolite; beyond this limit amphibolite covers a very wide horizon while gneiss comes down to a narrow stripe at Faydzabad migmatite contact.

In the Palang Darrah valley, at the amphibolite contact there is often green paragneiss with biotite, rich in iron oxides, titanite and apatite with not much evident schistosity and portions with incipient kaolinization (61 AP-136).

The common gneissic facies presents garnetiferous types with two micas, that are grey, regularly schistose and slightly banded (61 AP-134). Sometimes they contain sialic quartzous-feldspathic injections with amigdalar

expansions and garnet metablastesis in a gneiss paleosome with two micas, but prevailingly muscovitic (61 AP-134).

North-west of Palang Darrah, along the Sela-i-Kalan valley, a band of Rabat Gneiss of an average thickness of 500 m is inserted among the amphibolite and the gabbric masses of the pluton of Muzung. The lithological type is the usual one of the fine, grey, tubular, very biotitic paragneiss having small feldspathic eyes scattered in him (61 AP-129). The amphibolite contact does not show noticeable modifications, but towards the Muzung Gabbro the rock is enriched in chlorite and garnet, assuming a more marked tabular schistosity and a pale green colour (61 AP-126).

In the basin above Sela-i-Kalan the diorite contact happens with a facies with very marked lamellar schistosity, from the composition of garnetiferous micaschist (61 AP-125).

The head of the Kurkhu valley and its right hand side are formed by a heap over 1000 m thick of East Rabat Gneiss to which long marble are repeatedly mingled. On the right hand side of the valley the alternance of marble and gneiss is so thick it forbids the cartographical separation of the single elements. The gneiss is garnetiferous, fine-grained, zoned, very schistose as far as it foliates and iron-coloured (61 AP-90).

At the base, above the Kurkhu Gneiss, it is thickly injected with granitic material, both diffused and concentrated in aplitic and pegmatitic, also discordant, dykes. The diffused material gives rise to migmatitic biotitic-garnetiferous gneiss with sillimanite. This are banded, with the dark beds of paleosoma, clearly recognizable as biotitic paragneiss (61 AP-88, -89). At the marble contact there are often green-coloured bands as contaminations products with calcareous material, with the composition of migmatitic biotitic-amphibolic gneiss (61 AP-91).

Petrographical Features. — Two groups of rocks are evident, in the great variety of petrographical types forming the « Rabat Gneiss » they are: the fine gneiss with different transitions to a migmatitic gneiss and kinzigitic, the marble and calcphyre often joined to amphibolic gneiss and sometimes to amphibolite.

The group of sialic gneiss shows as a recurring type a fine biotitic paragneiss where quartz and feldspar form a homogeneous granoblastic compound in which the clastic border of some granule is now and then visible.

Sometimes feldspar is only plagioclasic, generally oligoclase or oligoclase-andesine, sometimes, on the other hand, there is a mixture of plagioclase and orthoclase in different quantities. Quartz is partially recrystallized and forms concordant stripes, at the contact of which small laminae and thin muscovite aggregates are developed. Biotite, on the contrary, is perfectly steady and distributed in a homogeneous way, in shape of small tabular strongly iso-oriented laminae, both isolated and in thin beds. Sometimes there are also amphibolic beds, generally of actinolite, in elongated prisms mostly substituted by biotite.

In the same types there is often a marked and general recrystallization with metablastic increase of biotite and sometimes also of muscovite in wide checkered levels among the quartzous and feldspathic granules. These transformations occur in concomitance with strong mechanical deformations, particularly marked in quartz and micas during their growth. Garnetiferous granules appear too.

In many cases, near the described transformations, there is the growth of eyes and glomeroblasts of plagioclase of andesinic $An_{30\text{-}35}$ composition, also placed in discordance with the fine schistose orientation, recalling those of the biotitic paragneiss. Here garnets are shaped like big idioblasts.

In the other cases, the glomeroblasts are made up of potash-feldspar, while plagioclase has the form of more or less poikiloblastic eyes. In such rocks, feldspar, mainly potassic, includes and strongly corroded quartz. No differences of composition are noticeable between the porphyroblastic plagioclase and that of the bottom mass. When there are differences, we notice a greater acidity of the porphyroblasts with the greatest difference of 12% An. In the types without lost the previous contexture of fine gneiss, it is noticeable an alternance of coarse quartz-feldspar granoblastic bands, of biotite-sillimanite aggregates with garnetiferous porphyroblasts, and feldspathic eyes of big dimensions.

Afterwards there are typical banded-augen kinzigitic gneisses that from the petrographical point of view are not well distinct from the ones in the Faydzabad and Kurkhu formations. A great range of calcphyre up to cornubianite, amazing for their typical associations of contact metamorphism, is developed in connection with the carbonatic bands included in the gneiss. The passage to the gneiss sometimes occurs with amphibolitic rocks sometimes with thick alternating beds and cornubianite.

Pure saccharoid marbles are scanty and at times they are full of iron minerals in a groundmass spathic calcite with microgranular relics; more often they are enriched in tabular euhedral flogopite laminae while the microgranular beds contain amphibolic crystals.

More seldon there are types containing a detrital quartzous-feldspathic fraction, in which calcite recrystallizes in flat, intensely iso-oriented specimens, while scapolite idioblastically increases. Scapolite is the most diffused mineral in calcphyre, where it now and then forms monomineral beds with granoblastic structure, or mingles with calcite as the only mineral joined to it. Generally in such types, in calcite are the marks of a recrystallization oriented following early specimens of smaller dimentions, with clastic form too, while scapolite appears in isometric idioblasts with strong unitary and late blasthesis.

The cornubianite bands generally are not as independent elements, but are related to the zones of greater metamorphic differentiation, also on centimetre scale. They too, are mainly constituted by a granoblastic scapolite aggregate with actinolite or hornblende, titanite, diopside xenoblasts in different quantities as hosts.

Into the amphibolic gneiss too, thick interposed beds and bands with variable composition from migmatitic to fine biotitic-amphibolic, to more homogeneous coarse-grained, gabbro-dioritic looking gneiss are visible. Plagioclase has an andesinic term with composition An_{28-35} also in the migmatitic types, where sometimes there is neoformation of potash-feldspar that is earlier than plagioclase. In these types, and above all in the farthest from the original paragneiss composition, hornblende is increased in euhedral prisms also later than granoblastic quartz.

Petrogenetical Considerations. — Rabat Gneiss, was originated by a metamorphism of lesser degree of the same pelitic-calcareous series forming Faydzabad Gneiss in the lowest part. It lies above the isograde of sillimanite with typical mineral associations of the staurolite sub-facies.

The pelitic and psammitic associations with quartz-biotite-garnet-plagioclase (muscovite-potash feldspar) prevail. Locally there are migmatitic facies with sillimanite, to be related to an anomalous increase of the metamorphic degree owing to granite plutonic masses of late intrusion as the one of Abu Abdal. In the rocks with calcareous derivation the following associations

prevail: calcite-scapolite-diopside-actinolite; calcite-diopside-flogopite, calcite-scapolite-hornblende-plagioclase (quartz). The described associations belong to the hornblende-hornfels facies, because, here too, there is the convergence phenomenon between regional and contact metamorphism, noticed in Faydzabad Gneiss. In them the most marked phenomenon is scapolitization much more intense than in the calcphyres included in Faydzabad Gneiss. It must be ascribed to the reactions occurred in the impure limestone with following liberation of CO_2, volatile component indispensable to the crystallization of scapolite. Probably a certain proportion of dolomite was present in the original carbonatic rock, and this could answer for the following formation of actinolite (tremolite) and diopside with elimination of CO_2. The original conditions for the formation of amphibolite are lacking. The amphibolic gneiss is essentially present as product of contact metamorphism of Abu Abdal Granodiorite, with the association plagioclase-hornblende-quartz-biotite, tipical of the hornblende hornfels facies to which, in another way, the rocks with carbonitic origin already mentioned, arrived too.

2.3. Qara Mughul Gneiss.

General Features. — Qara Mughul Gneiss forms the covering of Faydzabad Gneiss west of Faydzabad town, and stratigraphically corresponds to the Rabat Gneiss diffused in the region east and north-east of Faydzabad.

The petrographical analogies between the two types of gneiss are recognizable, while the distinction between them in the field was allowed by the intense compenetration and mingling of Qara Mughul Gneiss and Halqa Jar Amphibolite with the usual intercalations of marble and calcphyre levels, some of which had often considerable thickness and extension. The total thickness of the formation west of the Kokcha river is about 4000 m. Petrographically it is composed of fine biotite-garnet gneiss with markedly schistose, often zoned, banded or augen-banded texture.

The name comes from the village of Qara Mughul, lying about 7 km south-west of Faydzabad.

Field Observations. — Crossing east to west the interval between the Faydzabad Gneiss and the Petwan Blastomylonite, from Kokcha to Ganda Chasma through Qara Mughul and Eran Shah, it is possible to hawe a clear picture of the repeated interposition with gradual passage among gneiss, amphibolite and marble bands, to which are joined granitic and pegmatitic concordant injections. The passage to Faydzabad Gneiss is marked by an amphibolite band to which pegmatite concordant veins and lenses are joined.

After a narrow band with typical fine-grained biotitic garnetiferous dark coloured paragneiss with very regular, almost tabular schistosity (61 AE-1), a thick zone of marble and calcphyre up to 88 m thick is inserted. It continues as far as the north-western side of Faydzabad anticline with greater thickness Then fine biotite paragneiss with rather monotonous facies (61 AE-3) and amphibolite with minor carbonatic intercalations begin to alternate. The alternance generally occurs on a vaste scale with bands up to 400-800 m thick, but particularly at the contacts, there are metamorphic differentiations on a centimetre scale.

From the intermediate zone westwards, that is from a line passing through Itarchi-i-Bala, west of Kuri, and Eran Shar, the gneiss presents strong mechanical deformations oriented in concordance with the regional tectonics and schistosity. Owing to this, thick blastomylonite bands, with evident derivation from the common facies of the Qara Mughul Gneiss, appear (61 AE-13, -15).

Northwards, Qara Mughul Gneiss is less and less frequent until it appears in stripes and lenses into the huge amphibolite mass of Halqa Jar and it totally disappears near Qas Darrah, 20 km north of Faydzabad.

In the zone between Absiti and Turugh, 20-22 km from Qara Mughul, the proportion between gneiss and amphibolite lessens to 1:5. Crossing the Kokcha river, near Qara Quzi up to the Talbuzanak valley, it is noticeable a beatiful section of the tongue of Qara Mughul Gneiss, quite reaching the extinction zone.

The Faydzabad Gneiss is overlaid by a pile over 100 m thick made up of marble and calcphyre, followed by a very schistose biotitic garnetiferous gneiss (61 AP-51), to places rich in quartz-feldspathic eyes and veins. Greenish-coloured layers and bands of marble and calcphyre are repeatedly inserted in the gneiss. These layers are more or less markedly zoned, full

of scapolite, pyroxene, hornblende, titanite, and with quartz-feldspathic beds (61 AP-51).

At the amphibolite contact, amphibolic, thickly zoned, very feldspathic gneiss (61 AP-52) substitutes the biotitic gneiss for some hundred of metres. The same amphibolic gneiss with metasomatic albitic additions, is present as partially digested relics in the Naghz Darrah Tonalite near Zyarat-i-Kwaja pass, north of Talbuzanak.

Petrographical Features. — The most common facies of the Qara Mughul Gneiss is the medium or fine-grained partly augen biotite-garnet paragneiss with granolepidoblastic texture. Both of them are rich in quartz, with homogeneous composition of plagioclase that, quite everywhere, corresponds to andesine An_{30-35}; they have also many widely undulating biotite-lepidoblastic beds. Even if it has a good stability, garnet is generally in small granules split up along the schistosity planes.

Macroscopically visible porphyroblasts are scantier and always in connection with lenses and feldspar eyes of late growth. In this case they are plagioclase eyes with andesinic composition and more seldom of potash feldspar. In such types there is often remobilization of quartz with recrystallization in stripes and concordant lenses.

Amphibolic-biotitic gneiss has a homogeneous granoblastic texture where hornblende sub-idiomorph prisms isolatedly grow, sometimes along schistosity planes, and turn into biotite. The plagioclase of these gneisses is more calcic than the one of the biotitic-ganetiferous types, and presents an average composition An_{40-45}. Some of them are interested by a late albitization.

2.4. Halqa Jar Amphibolite.

General Features. — The Halqa Jar Amphibolite forms a now massive, now stratified body, about 4000 m thick.

It lies in concordance on Faydzabad Gneiss, substitutes the medium-upper part of Rabat Gneiss and repeatedly alternates with Qara Mughul Gneiss, together with crystalline limestone lenses and layers. Amphibolite crops out on a wide area north, north-west and west of Faydzabad and is called

after the village of Halqa Jar situated on the left hand side of the Kokcha river, downstream from Faydzabad.

On the northern side the amphibolite contacts the plutonic masses of Muzung and Naghz Darrah. The second of them mainly suffers considerable endomorphism phenomena at its contact.

Along the western margin the formation is sharply divided from the Kakan pluton by a thick band of mylonites connected with late movements of the Upper Amu Darya Depression.

Massive, slightly schistous, medium or fine-grained amphibolite prevails. It has banal composition often with unhomogeneous distribution of the sialic beds. Sometimes there is zoned amphibolite, mainly in the basal part.

In the amphibolite bands alternating with the Rabat Gneiss we can see zoned texture and mixture with carbonatic minerals together with cornubianitic structure.

Field Observations. — In the peripheral parts of Faydzabad Gneiss there are intercalations of thick and long amphibolite bands that are generally joined to saccharoid marble and calcphyre with scapolite, cordierite, pistacite and titanite. They are particularly developed at the north-east margin of the migmatitic outcroppings, where a single amphibolite horizon is found stretching along 12 km from the Kokcha as far as the village of Pular. Another thick band of amphibolite intercalations in Faydzabad Gneiss is south of the Kokcha, along the Spin Gaw valley.

North-west of Faydzabad we can see that the same amphibolitic intercalations continue in Qara Mughul Gneiss with slow and progressive transition to migmatites. Further away from the contact, the amphibolite bands thicken, becoming a mass devoid of stratiform orientation. These passages can easily be observed along the Zin Darrah valley, between the village of Cakolc and the Kwaja pass.

In the lowest part of the valley, upon a thick horizon of marble outcropping round Cakolc, we see a thick interposition of fine paragneiss with biotite (61 AP-51), zoned amphibolic gneiss (61 AP-52), and fine-grained slightly schistous amphibolite (61 AP-53). Quartzous-feldspathic veins with amigdalar forms persist in the gneiss. In smaller there are layers of calcphyres with scapolite, clinozoisite, pyroxene and hornblende (61 AP-50).

Above the village of Talbuzanak only the more or less schistous amphibolite remains. They are sometimes epidotic with sialic beds and lenses with discontinuous and irregular trend.

Near the pass and north-west of it, on the slopes overhanging the village of Kawoz, the amphibolite is intensely injected by quartzous-plagioclasic material (61 AP-64) connected with the tonalitic pluton of Naghz Darrah. In the tonalite too, there are half-digested inclusions of amphibolitic origin (61 AP-58/1).

An analogous lithological sequence is noticed from Bozgeran towards the pass 2438 m high north of the village. Here too the amphibolite is prevailingly schistous, injected, and have a great variety of passages to amphibolic gneiss up to biotite amphibolite. There are also scattered intercalations of marble and calcphyre.

At the contact between tonalite and gabbro of Muzung near Darel, there is the usual fine, slightly schistous amphibolite, now and then injected with sialic plagioclasic material (61 AP-113). The marble beds in the amphibolite are evidently enriched in green contact minerals, among which there is pistacite and pargasite (61 AP-114).

Downwards in the Peseyel valley there is again fine slightly zoned green-coloured amphibolite and forming the prevailing type in the amphibolic outcroppings in the middle of Naghz Darrah pluton. An analogous type of amphibolite is in the narrow bands toghether with gneiss and marble, near the contact with the tonalite upstream of Sela-i-Kalan (61 AP-127).

Along the eastern margin of the pluton the widest outcrops, having the greatest homogeneity of facies in the amphibolitic formation, appear. Its complete section can be seen along the Langac valley, between the villages of Deh-i-Tagab and Rangh Darrah. There are massive fine-grained, very compact, sometimes zoned, amphibolites (61 AP-133) that follow one another without noteworthy variations up to 1500 m thick.

At the tonalite contact they show sialic nest-shaped injections, veins and lenses arranged in a little homogeneous way in the mass. The passage to Rabat Gneiss occurs with the presence of biotite, then muscovite and garnet (61 AP-134) at an interval of few tens of metres.

Petrographical Features. — The amphibolite of Halqa Jar formation essentially differs from the one intercalated in Faydzabad Gneiss on the

more acid character of plagioclase, the lack in cornubianitic structures and the frequent presence of epidotes.

The leucocrate gatherings are frequent: they are both conformable in bands, stripes and lenses and unconformable in heterogeneous spots and dapples, particularly at the contact with bodies of granitic rocks. The texture of the most amphibolitic parts are lineated up to slightly schistose. Essential components are green hornblende and medium acid plagioclase that is always anhedral in comparison with amphibole, as quartz is an additional component often lacking.

The two essential components in many cases divide in amphibolic and plagioclasic-amphibolic beds by turns, forming fine-zoned texture. Frequent minerals are, on the other hand, titanite, magnetite and ilmenite. Epidote has variable distribution; it often thickens at the contact with sialic bands in some amphibolites near the masses of granitic rocks. This epidote is generally made up of clinozoisite prisms, more seldom of zoisite and pistacite.

Plagioclase generally has a composition of basic andesine $An_{40\text{-}48}$, more seldom of acid andesine with oligoclase-andesine, sometimes labradorite up to $An_{56\text{-}58}$. There are no different compositions between the plagioclase joined to hornblende and the ones of the leucocratic zones. The last have prevailing plagioclasic composition with heterogranular structure with some interstitial quartz at times.

An increase on the plagioclase basicity is noticeable in the amphibolite with heterogeneous texture, where, near fine granoblastic zones, big hornblende and labradorite idioblasts are intergrowing. There is labradoritic compositions in some plagioclasic bands with cornubianitic structure included in zoned amphibolite. Some of them show alternating feldspathic and actinolitic beds containing diopside at the contact with which epidote and zoisite prisms develop.

Some actinolitic schists outcropping at Muzung Gabbro contact also belong to Halqa Jar formation. They are characterized by a marked retrograde metamorphism. They are prevailingly monomineral skarns with actinolite in bundles of fibrous prisms ending with flames, where some of them increase as porphyroblasts often bound by a felt-shaped aggregate made up of often undistinguishable specimens. In some types epidote interstitial nest with micro-granoblastic structure appear. Other contact facies among

Muzung Gabbro and carbonatic bands in the amphibolite are represented by calcphyres with pistacite, pargasite and garnet. In the bands of calcphyres repeatedly included in the amphibolitic mass, even if far from magmatic masses, the essential minerals are calcite and scapolite with smaller quantity of pyroxene, hornblende and titanite. The first two are often in monomineral beds or in beds with mutual mixture with granoblastic structure. Quartzous feldspathic beds with basic plagioclase up to labradorite An_{60-65} and sometimes orthose, microcline and interstitial quartz alternate to these calcphires.

PETROGENETICAL CONSIDERATIONS. — Halqa Jar Amphibolite, in comparison with Rabat Gneiss and Qara Mughul Gneiss, is a product of isograde metamorphism, beginning with original materials with different composition. The evident lateral substitutions and the repeated intercalations of gneiss and amphibolite that on the ground allowed to formulate such hypothesis were already described. The prevailing mineral association is the following: hornblende-plagioclase-epidote (quartz) typical of the staurolite-quartz subfacies belonging to the almandine-amphibolite facies.

Unlike the calcic plagioclase contained in the Faydzabad Gneiss, intermediate, namely andesinic terms, prevails in the amphibolite outcropping north and east of Kokcha. The coexistence of a medium plagioclase with epidote is peculiar of this sub-facies according with FYFE, TURNER & VERHOOGEN (1958) and others.

In the limestone intercalations there are the same associations described for the analogous types joined to Rabat Gneiss, and this confirms the isograde character of metamorphism acting on the two formations.

On the nature of the rocks that gave rise to this thick amphibolitic series, we can just set forth some hypotesis.

First of all we can distinguish in the amphibolitic formation two zones with different characters of composition and lying; a southern and stratigraphically inferior zone, with thick amphibolite, marble and biotitic paragneiss (Qara Mughul Gneiss) intercalations; a northern zone with massive amphibolites seldom joined to marble lenses.

In the first type there are the texture and composition unhomogeneity and the calcic character of the plagioclases already noticed in the amphibolite of Faydzabad Gneiss. The only difference with the last is the presence of epidote, because they belong to a zone of lower metamorphism.

According to FYFE, TURNER and VERHOOGEN, epidote is unstable under the highest temperatures typical of the sillimanite-almandine sub-facies. For this type we would be inclined towards a sedimentary genesis starting from a pelitic-arenaceous series with marble-dolomite or tuff intercalations.

As has already been said, in massive amphibolite the character of plagioclases is more acid andesinic or oligoclasic; quartz is absent. The massive lying is reflected on a great texture and composition homogeneity that is upset only by sialic intrusive masses. The equilibrium of the associated hornblende-epidote-plagioclase is unusually stable.

Once stated the constant zonality in metamorphism, it seems rather difficult to think of a variation of facies in the original sedimentary series, such as to produce an extremely uniform product thousands of metres thick. On the contrary, we consider it possible that the massive amphibolite corresponds to the metamorphic product of an igneous basic mass consolidating in the sedimentary series itself, or of a volcanic basaltic apparatus from which perhaps the stratoid amphibolite of Qara Mughul zone would derive.

2.5 Kurkhu Gneiss.

GENERAL FEATURES. — Kurkhu Gneiss represents the most thick migmatitic formation in the region widely stretching along the Warduj and Zardew valleys and extending north-east as far as the Lake Shiwa zone. All together it forms a band about 10 km large, grading west and north-west to Tarang Gneiss and Bakarak Granodiorite, while south-east it is covered by Rabat Gneiss. Its name comes from the village of Kurkhu, lying on the left hand bank of the Zardew river.

There are augen or augen-banded gneisses with biotite, garnet and sillimanite with palasome of sialic gneisses quite wholly reabsorbed in the lower part of the series. In the upper part a thick banded texture is developed. It is accentuated by the presence of prevailingly concordant veins with pegmatitic or granitic nature. Sometimes there are concordant hybridization zones of dioritic composition.

FIELD OBSERVATIONS. — The valley of the Kurkhu river, left tributary of the Zardew, crosses all the migmatitic formation that appears in mono-

cline series with variable trend from N 25° W to N 25° E, dipping W with strong inclination up to vertical.

At the bottom of the valley, about 2000 m high, Tarang nebulites grade to rocks with more regular schistose orientation, where the spots with granitic and granodioritic compositions are placed in bands concordant with the schistosity until it resembles orthogneisses with coarse-grained biotite (61 AP-95). To these type, bands of very sialic augen gneisses alternate. They have beds of biotitic gathering, and so thin and scattered to give the whole an intensely zoned and banded look. At the altitude of 2200 m there are augen migmatitic gneisses with biotite forming a monotonous facies prevailing up to about 2500 m. These gneisses have massive fine-grained compact, not very micaceous, very laminated and diaftoritic palasome with augen feldspathic porphyroblasts up to 2-3 cm large (61 AP-94). The medium and upper part of the series is characterized by migmatitic gneiss with sialic, pegmatitic or granitic veins, in a dark, grey-greenish matrix with garnet and partly cloritized sillimanite (61 AP-93). The contraposition between metasoma and palasome is much marked also on the outcropping surfaces; from it a sequence of bands 1 to 10 cm thick come and the sialic ones often show much marked plastic involutions.

Sometimes ibridation zones with dioritic composition are produced. They have dark mafic, schistose, ill digested spots. Towards the top from granular and massive the matrix becomes more and more schistose, very rich in biotite and garnet (61 AP-92).

The sialic bands, formerly thickly placed bed to bed, now thin away and assume the shape of small dykes unconformable with the schistosity. In palasome bands of dark grey fine-schistous biotitic-garnetiferous paraneiss are visible. So the formation slightly grades to Rabat Gneiss that surrounds with steep valls the whole head of Kurkhu valley as far as the peaks about 5000 m high of the Koh-i-Khus-Darrah. Even if in this zone also the Rabat Gneiss is migmatitic, it distinguish itself for the insertion of long and thick marble layers with amphibolic enrichments very similar to the ones described along the Kokcha valley.

Petrographical Features. — It is a considerably augen or augen-banded migmatitic gneiss with biotite, garnet and sillimanite, where the coexistence of a palasome of fine biotitic gneiss with a quartzous-feldspathic metasome,

is very evident. In palasome, in spite of the strong recrystallization particularly suffered by quartz, a pristine fine granolepidoblastic aggregate is recognizable. In it an intense feldspathic metablastesis occurred in biotitic, biotitic-garnetiferous or biotitic-garnetiferous-sillimanitic beds, lenses or crumpled bundles. Many feldspathic eyes increase in the rock more or less markedly, surrounded by a wrapper made up of the above mentioned metablastic crystals but also simply surrounded by a rim of microgranoblastic quartz with isolated biotitic tabular laminae, shaped to their borders.

Sometimes the feldspathic eyes increase at the expenses of fine plagioclasic aggregate forming palasoma. They are prevailing formed by oligoclase rather limpid crystals with uniform composition An_{25-28}, with polysintethic diffused but not too evident twins, among which there are frequently the Albite-Ala ones. Now and then they have a reaction border with albite composition. To a smaller extent the eyes are formed by glomeroblasts made up of polygonal crystals that partially interpenetrate, and of orthose, perthite and oligoclase with mirmekitic structures.

The behaviour of quartz shows many deformations and blastesis phases. Besides the fine granoblastic quartz of palasome, there is cataclastic quartz with partial lense or stripe-shaped recrystallizations that are clearly included and corroded by the feldspars of neoformation.

A later crystalloblastesis of quartz has limpid patches that in their turn corrode the feldspathic eyes and the garnetiferous metablasts. In the meantime there is a partial recrystallization and increase of the biotite in tabular patches of big dimensions and in radial groups placed with more or less discordant lying with the lepidoblastic bundles and partially increased at the garnet and the sillimanite expenses.

In some cases the deformation phase preceding the increase of feldspathic porphyroblasts took the features of a real dynamometamorphism with lamination planes mainly along the micaceous beds and shearing planes among quarzous blastomylonitic oriented bands. These actions seem to have occurred until the beginning of the feldspathization phase, the products of which seem to be interested by clear paracrystalline deformations. In the same rocks, a total chloritization of biotite and a kaolinization of the feldspars of variable importance in the different zones appears.

Petrogenetical Considerations. — Among the metamorphic forma-

tions of Central Badakhshan the Kurkhu Gneiss represents the greatest genetical complexity. First of all it is evident that it is a polymetamorphic product consisting in two phases of regional character at least, of which the most recent is joined to vast migmatization and granitic intrusion processes.

According to SEDERHOLM's terminology Kurkhu Gneiss corresponds to arterites provided with extraordinary rhythmic and intensity in the alternation of leucocratic, mesocratic and melanocratic veins and bands. Lense-shaped and augen expansions are joined to them together with differential mobilization phenomenon of the leuco and mesocratic ones in comparison with the beds of mafic minerals.

These movements often occur as oblique shearing causing discordant folding that ends in agmatitic structures. So, the mineralogic composition that on metrical scale is homogeneous, on centimetral scale splits into minor associations where iperalluminose metasedimentary zones, and other with granitic to granodioritic composition, enriched in Na, are recognizable. Also melanocratic-amphibolic or amphibolic-plagioclasic beds with more calcic plagioclase than in the country rock appear. Often all these elements base thenselves on an augen or banded augen mesocratic gneiss.

Kurkhu Gneiss downwards grades to the granodioritic mass of Baharak through the nebulitic band of Tarang and is covered in concordance with Rabat Gneiss. Stratigraphically they have the same position of Faydzabad Gneiss. A metamorphic formation laterally equivalent to the metasedimentary series of Faydzabad underwent a new metamorphism phase converging with rocks of granodioritic composition intruding in the overhanging ground, also with low metamorphism degree as the black slates.

The gneiss of the old cycle suffered intense mechanical solicitations, partially developed along planes unconformable with the old schistosity surfaces. In fact the new metablastesis structures were originated along mylonitic beds and bands often accompanied by a schistous reorientation of palasome.

The last migmatization processes seem to be overlying a metamorphic lesser degree, where the tectonic epidermal solicitations subsist. This also caused wide diaftoritic recrystallization processes and anomalous mineralogic associations. In the quartz-sillimanite-biotite association of palasome, calcic plagioclase is by degrees substituted by sodic terms, up to oligoclase.

The original amphibolic beds turn into biotitic-amphibolic or chloritic-biotitic schists.

After all, Kurkhu Gneiss must be considered as a thick band of metasomatic transformations and of magmatic peripheral injections of Baharak pluton, that arose to medium or low metamorphism zone instead of as a product of progressive granitization of a regional high grade metamorphism.

2.6 Tarang Gneiss.

General Features. — Along the southern margin of the Baharak Granodiorite mass, there are wide gneiss inclusions with nebulitic texture connected to one another by thin beds and schistous films. So there is a formation of nebulitic and anatexitic gneiss called Tarang Gneiss, after the name of the village on the left hand side of the Warduj valley.

The lying of this formation is rather irregular and discontinuous as it clearly follows the structural and morphologic position of the granodioritic pluton, wrapping it at the base, and partially covering it on the eastern part.

Field Observations. — In this zone Tarang Gneiss is, above all, at the foot of great walls of Koh-i-Hazar-Chasma along the Zardew valley passing southwards into the Warduj valley as far as Chakaran. The anatexitic gneiss have a range of types from sialic to clearly more mafic beds and bands, with the composition of amphibolic gneiss. In the sialic contexture, granodiorite and microgranodiorite appear as dark nebulitic spots without clear limits.

The gneiss is migmatitic, and with plagioclase eyes irregularly placed (61 AP-158), sometimes rich in potash feldspar (61 AP-86). Now and then, in the Kurkhu valley mainly, there are migmatitic banded very sialic gneiss where neosome is made up of band and lenses with granodioritic composition (61 AP-84), inserted bed to bed into dark bands of amphibolic gneiss (61 AP-85).

Homogeneization zones are frequent, and generally microgranular, in them the rock has the composition of a leucogranodiorite (61 AP-87). They

are recognizable as dark-green spots with shading borders into the sialic gneiss contexture.

PETROGRAPHICAL FEATURES. — Heterogeneous migmatite that is assentially made up of more or less nebulitic anatexite belong to this group. It pass to leucogranodiorite that is generally more basic than the one of Baharak and that enclose bands of amphibolic gneiss.

Anatexite is rather sialic and has augen banded texture with potash-feldspar and plagioclase porphyroblasts plunged into a very quartzous matrix with scarce biotite. Plagioclase with more acid composition than the eyes in the Kurkhu Gneiss, corresponds to oligoclase An_{15-18}. Potash-feldspar is given by orthose and is often antiperthitic.

As in Kurkhu Gneiss at least two generations of quartz are recognizable. An older one in lenses and stripes made by intense cataclasis and subsequent blastesis in clearly synkinematic conditions, and a later one with heterogeneous granoblastic patches intensely corroding the feldspars. Biotite appears recrystallized but scarcely increased on pre-existent aggregates fibrous and turbid-looking. Other types of gneiss, particularly diffused near the Baharak granodiorite contact, present big porphyroblasts and glomeroblasts of andesine up to 38% An, completely lacking in mechanical deformations, with beautiful albite, albite-carlsbad and albite-pericline twins, plunged into a rather schistose contexture very rich in biotite and with quartz in strong paracrystalline deformations, partially relaid in fractures. In these types potash-feldspar is absent.

After them there is frequently a very homogeneous gneiss with aplogranodioritic composition, but normally rich in quartz (more than 50% of the total composition), where plagioclase reaches an oligoclasic composition up to An_{26-28} and potash-feldspar is subordinated to it. Quartz appears completely recrystallized under strong paracrystalline deformations and gathered in patches of big dimentions, later than the crystallization of feldspars. At the end of this phase a sensible increase of biotite that reaches the 10% of the total composition occurred.

In the leucogranodiorite included in form of spots into the migmatitic gneisses, we see a clearly more basic character of plagioclase that appears with oligoclasic-andesinic terms up to a content of 31% An. In concomitance

plenty of green hornblende joined to biotite appears, so that the quantity of mafic components grows up to more than 15%.

In these rocks there is a complete recrystallization of quartz in microgranoblastic form that quite wholly effaces the marks of an earlier cataclasis. Also plagioclases appear very fresh, with uniform composition and well signed borders, with frequent albite-ala twins, as we noticed in granodiorites of Baharak pluton.

The amphibolic gneiss included in bands among the sialic gneiss and often alternating bed to bed with them presents a certain structure affinity with the granodiorite, though it is clearly more basic. Plagioclase is an andesine with content up to 45% An that appears crystallized together with the mafic components, giving a granoblastic aggregate in which the schistose orientation is produced by the biotitic flakes. Quartz, in secondary quantity, is in roundish much corroded relics bearing the marks of earlier paracrystalline deformations.

Petrogenetic Considerations. — Tarang Gneiss does not form a genetically indipendent unit but it must be connected with cycles of metamorphism and migmatization that originated Kurkhu Gneiss moreover, it forms the innest peripheral band, partly granitized of the granodioritic pluton of Baharak. Most of it must be considered as made up of nebulites, in which granitic or granodioritic elements widely develop without sharp limits with the host rock, but also agmatites with mafic schlieren and arterites with intensely crumpled bands appears. The host rock, though with gneissic texture, acquired granitic composition, quite wholly quartz-feldspathic, with the micas that are sometimes completely readsorbed. The meso and melanocratic bands that in the Kurkhu Gneiss represented metasedimentary palasomatic relics, here mostly have igneous, granodioritic character, or are represented by rather homogeneous and slightly schistose amphibolic gneiss with andesinic plagioclase. It is rather difficult to state the original nature of the rocks that suffered granitization.

According to experimental anatexis proofs, H. von Platen (1965) stated that in gneiss with excess aluminium, as Kurkhu Gneiss, containing biotite, sillimanite and quartz, the anatexic fusion gave birth to potash-feldspar and cordierite. The latter, under high pressure, is substituted by almandine.

Neither cordierite, nor almandine were found in Tarang Gneiss. In the

same gneiss, moreover, the carbonatic intercalations that characterized Faydzabad Gneiss are absent.

This cannot be explained with a complete dissociation of calcite and, even if the thermodynamic conditions of metamorphism were so high to allow it, the reaction products that would have derived between calcite and quartz, and between calcite and silicates, are lacking (N. L. Bowen & C. E. Tilley, 1951).

We can so conclude that Tarang Gneiss was originated by the partial recrystallization of a lithologic complex different from the one of Kurkhu Gneiss, forming the base of the last, and probably of the Faydzabad Gneiss. The petrologic data above discussed show that this original lithological complex, partially has the features of an igneous kalk-alkaline rather homogeneous complex, that probably underwent an older metamorphic cycle.

2.7. Black Slates.

A thick series of dark-coloured arenaceous and clayey slates intercalated to the calcareous-dolomite formations, cross north-southwards all the eastern part of the surveyed region dividing the migmatitic zone of Baharak—Kurkhu—Lake Shiwa from the zone of Faydzabad.

Tectonically it is a zone with synclinal trend, narrowing south of the Jurm valley, wider and more divided into imbricated flakes in the zone north of the Kokcha river. Along the western margin black slates contact the oldest calcareous-dolomite formations grading to Rabat Gneiss, probably of Lower Paleozoic age.

In the central part, on the other hand, they are enclosed in the Wuran Shahr limestone of the Upper Jurassic, and the Kalawch limestone of the Upper Devonian.

In the same zone a fossil flora belongs also to the black slates. It is of Upper Triassic age and was found in the first valley on the left side of the Darya-i-Kalawch, at an altitude of 2840 m above sea level.

Eastwards, black slates are limited by the granodioritic mass of Baharak, exercising on them a strong thermic metamorphism. For this reason

the black slates may be composed by different formations inserted in different positions in the carbonatic Palaeo-Mesozoic series. Two formations of black slates at least should be represented: one of the Lower Palaeozoic (Silurian) lying on Sur Khan Limestone and on the Pa-in-Shahr Formation and having the highest thickness of the black slates, probably more than 1000 m thick, one of Triassic age, forming a band of lesser thickness enclosed in the central part of the flakes system. A further detail is difficult because of the complex tectonic situation of the zone. On the whole black slates are characterized by clayey and fine arenaceous slates more-or-less graphitic, dark grey to black coloured in relation to the grain and the graphite content and, generally, except some coarser arenaceous facies of a very clear schistosity.

The mineralogic composition of these rocks is quartzous-sericitic-chloritic with various relations between quartz and the other components. In the basal part, the amount of quartz increase and locally plagioclase also appears. So, it is possible to locate a horizon 150 m thick mainly formed by quartz and quartz-feldspathic metamorphic sandstone, light-grey to white-coloured, rather compact and in well distinct layers (61 AP-78, -149, -151). It is recognizable along the western margin of the black slates from Pa-in-Shahr as far as Koh-i-Sur Khan, that is as far as the spurs of the Darwar range. It appears again in the flakes zone around the Wuran Shahr pass and in the synclines with core of black slates developed on the left of the Shiwa river. It is a guide horizon that will be used to clarify the complex tectonic and stratigraphical relations among black slates and calcareous Mesozoic and Palaeozoic formations in the region north of the Kokcha river.
Another interesting lithogical motive is given by a puddingoid to conglomeratic horizon inserted in the basal part of the black slates, between the calcareous-evaporitic formation of Pa-in-Shahr and the horizon of quartz-feldspathic sandstone and quartzite just described. Such a level can be followed along the bottom of the Pa-in-Shahr valley from 1770 m above sea level as far as the outskirts of village of Wurhel. It chiefly shows roundish and sometimes sub-angular elements of grey, yellow, and hazel-brown crystals plunging in abundant fine calcareous cement that is sometimes laminated and with micaceous beds (61 AP-147). Among the coarse clastics, stratoid films of greenish sandstone with prevailingly calcareous recrystallized cement and quartzous clastic are also inserted (61 AP-148). Both in these

arenaceous types and in the pelitic slates, the metamorphism degree is low and the transformations are essentially textural; the only minarelogic transformations noticeable consist of the recrystallization of white mica and of the neoformations of chlorite. For further information on the petrographical and petrological features of the black slates can be seen in the chapter on the Lake Shiwa region.

2.8. Kaferan Marble.

The Kaferan Marble is the deepest formation among the metamorphic calcareous formations of the studied area. It presents a monotonous succession of well-bedded crystalline limestones, rich in white micas and somewhat schistose at the base (61 AP-137, -138). In the middle and upper parts light coloured marble predominate (61 AP-140, -141). The contact with Rabat Gneiss seems to be stratigraphical and made up by some interlayering without gradational lithotypes. The tectonic position corresponds to the core of narrow synclines in the Rabat Gneiss, oriented roughly north-south and steeply dipping.

2.9. Sur Khan Limestone.

This formations is constituted by grey and black limestones, somewhat dolomitic, conformably covering the Upper Devonian Kalawch limestone. The rock im mainly crystalline and detritic (61 AP-150, -156) especially in the upper levels, where it grades into the basal quartzitic horizon of the Black Slates. It lies in long and wide synclines trending north-south, and having the black slates at the core. The Sur Khan Limestone outcrops between Wuran Shahr Pass and Shiwa valley.

3. COMPARISON OF THE METAMORPHIC UNITS WITH THOSE OF PAMIR.

Vast magmatic and metamorphic complexes have been recorded in Pamir, but our knowledge of these is incomplete and does not enable a clear correlation with the analogous lithological units which outcrop in Badakhshan to be made. Generally the high grade metamorphic rocks are mainly of Precambrian age. Precambrian metamorphic complexes have been described by VLASOV & GUILOVSKYI (1968) in the northern part of the Northern Pamir. The main lithotypes present are two micas gneiss and micaschist, frequently with garnets and staurolite, quartzite, phyllite, slate and marble. According to these authors there are four stratigraphically separate complexes with a total thickness of more than 10.500 m. However, BORSHITSKAYA previously considered them to form part of a single series.

ARKHIPOV, LEONOV & NIKONOV (1970) gave a general description also of the Precambian metamorphic rocks in Pamir as well as their extension into southern and south-eastern Badakhshan, where they underlay Ordovician sedimentary rocks with trilobites. Mesozoic metamorphic formations were, on the other hand, recorded by LEVEN (1960) in the Muskol complex, which occurs widely in Central Pamir. LEVEN maintains that the metamorphism of this complex is strictly related to the magmatic activity of Late Cimmerian or Alpine age. In order to sustain this hypothesis the author presents numerous palaeontological proofs, especially for Triassic or Jurassic in the metasediments which form the complex. The stratigraphic sequence in the Muskol complex includes a thick series of schists and phyllites containing Late Triassic flora and these are followed by sandstone, conglomerate and carbonaceous rocks, locally with dolerite lenses and marble with amphibolite, volcanics and conglomerate with Middle Jurassic coral debris. The sequence of marbles passes laterally into schists and gneisses with thick amphybolite intercalations.

Palaeozoic metasediments are, however, present over wide areas in the Northern Pamir, according to LEVEN (1960). These are the Darvaz-Sarykol complex of Devonian age and the Ordovician Tuzguny-Tereksej complex. This latter consists of a thick complex sequence of phyllitic and arena-

ceous schists, siliceous schists, shales and marbles containing trilobite, brachiopod, crinoid and cystoid faunas.

The Darvaz-Sarykol complex comprise a monotonous sequence of phyllites, chloritic or quartz-chlorite micaschists, carbonaceous chloritic schists and quartzites. On this complex, referred to the Devonian on the presence of fragments of crinoids, there is a succession of coarse volcanic sediments with an estimated thickness of many thousands of metres. These are overlain by a thick conglomeratic-arenaceous sequence with calcareous intercalations of Carboniferous-Permian age.

In Badakhshan also, to the east of the Petwan mylonite belt, it is possible to recognise a close association between metamorphism and granitizations as well as a clear relationship between the high grade metamorphic successions and the epimetamorphic sedimentary formations of Palaeozoic and Mesozoic age. The kinzigitic core of the Faydzabad gneiss reveals a bed by bed injection of sialic material which locally assumes a clearly granitic composition. A vast mobilisation of sialic material appears in the overling amphibolitic Halqa Jar series, concomitant with the emplacement of the Naghz Darrah Tonalite. This last intrusive event appears to have occurred at the same time as the metamorphic alteration of the volcanic-sedimentary sequence from which the Halqa Jar Amphibolite originated. Further to the east, in the Warduj and Zardew valleys, the thick series of Kurkhu migmatitic gneiss is developed, which becomes progressively nebulitic and forms passage rocks to the Baharak Granodiorite on one hand, and to the Rabat biotite-garnet gneiss on the other. The Kurkhu migmatites, therefore, appear to occupy a stratigraphic position equivalent to that of the metamorphic formations in the Faydzabad area outcropping further to the west.

It should be noted also that in a large area to the north and northwest of Baharak, epimetamorphic sedimentary formations, ranging from Devonian to Jurassic, are found. Among these, the black slates, in part at least of Neo-Triassic age, show clear discordant relationships with the intrusive Baharak granodiorite as Bordet & Boutière (1968) have also observed. Therefore it can be stated that, as observed by Leven in the Central Pamir, the metamorphic sequence of Central Badakhshan must be in great part related to the magmatic-metamorphic activity of Late Cimmerian or Alpine age which affected the Palaeozoic and Mesozoic sedimentary sequen-

ces. A part of this sequence escaped the intense alteration and this one outcrops north and north-west of Baharak. Here it is possible to recognise similarities between it and the Muskol complex in the Central Pamir.

Both in Central Badakhshan as well as farther east around Lake Shiwa there is a more or less well defined metamorphic zone which passes from hornblende-granulite facies to green-schist facies within a small distance. This change of facies is occasionally masked by the development of contact metamorphic facies caused by post-Jurassic granite masses. The picture is similar to that described by Davydenko (1966) for the Wakhan and Rushan metamorphic series in South-west Pamir. Among the sequences which indicate different facies successions in South-west Pamir there are many basic horizons, rich in CaO, which on the whole resemble the metamorphic zones revealed by basic horizons in the Faydzabad, Halqa Jar and Muzung formations. Certain similarities, moreover, can be seen among the Badakhshan granodiorites formed by anatexis and those described by Davydenko in the Darsha area.

The work by Shanin et al. (1969) has revealed important differences in the absolute age of minerals in the Wakhan metamorphic sequence of South-west Pamir. In particular, they obtained an age of 1750 M.Y. in the centre of large phlogopite laminae, while the margin showed an age at least 1000 M.Y. less. Ages ranging from 10 to 30 M.Y. were found in other phlogopite micas as well as biotite, potassic feldspars and amphiboles. According to these authors, these phenomena are the result of a general rejuvenation of the minerals containing K and Rb during the Neogene, when great vertical movements of the crust took place. Their original metamorphic state was acquired during the Proterozoic, as a result of migmatisation and granitisation.

The polymetamorphic character of many of the rocks of eastern Central Badakhshan, as indicated by petrographic evidence, is reinforced by the results given in the publication cited above although in the area studied the Alpine metamorphism clearly reveals dynamothermal characteristics, while a late synkinematic recrystallization similar to that postulated by Shanin et al., appears to be limited to the blastomylonitic belts located at the contact between Central Badakhshan and the Kataghan depression.

C. PLUTONIC ROCKS

1. INTRODUCTION.

In this chapter are described the igneous rocks of the entire area mapped, represented on the geological map attached and also the neighbouring area visited rather superficially.

The rocks have been arranged according to lithologies, which are also the types which comprise the various igneous bodies outcropping in the studied area. In fact these bodies are very different from one another not only in petrogenetic process from which they have originated.

The greater part of these igneous bodies are mainly sialic and the lithological types of which they are composed have been distinguished by the following names:

1. Abu Abdal Granodiorite,
2. Baharak Granodiorite,
3. Naghz Darrah Tonalite,
4. Jalmish Tonalite,
5. Kakan Quartz Diorite.

Among the igneous rocks, basic types are also represented, and the

6. Muzung Gabbro belongs in this category which comprise gabbro with transitions to gabbro-diorite and variation to sialic rocks (Naghz Darrah Tonalite).

It has already been stated that the lithological differences depend on the various types of petrogenetic process and age. It must be mentioned here that ages of the igneous rocks of Badakhshan have been determined not only by their stratigraphic position, but also by radioisotopic methods (Desio, Tongiorgi & Ferrara, 1964). We will deal later with this subject.

2. DESCRIPTION OF THE ROCKS.

2.1. Jalmish Tonalite.

General Features. — Jalmish pluton was observed on a distance of above 60 km at the south-eastern margin of the Upper Amu Darya Depression in the form of a thick mass of granular acid or intermediate rocks, placed in concordance with the structural trend of the metamorphic core of Central Badakhshan.
The eastern part of the mass forms high and massive reliefs with alpine morphology, formed by tonalite and quartz-plagioclasite with leucogabbric marginal facies, while in the core of the pluton, leucogranitic and aplogranodioritic types are prevailing.

North-eastwards, on the other side of the Mashad valley, the pluton has narrow and elongated form, and is accompained by thick mylonite bands that, on the lying point of view, make it similar to the Kakan pluton. The rocks of this apophysis are made up of quartz diorite, amphibolic diorite and tonalite.

Field Observations. — The most conspicuous part of the pluton seems to form the reliefs south of Kishem and east of Farkhar: rather big mountains, and with rough quite alpine morfology, in some places (Plate VI).

Near this central part, the contact with the Farkhar Slate seems particularly sharp, wihout marked metamorphic phenomena although it is evident relation of intrusion between the pluton and the slates. The only injection phenomena of sialic material in the slates were noticeable on the left side of the Mashad valley, near the Darrah-i-Shah-Baba bridge. The intrusive material and the one forming the margin of the pluton itself appeared of the same nature, that is corresponding to a quartz-plagioclasite (61 AD-32).

Further westwards, near Darrah-i-Jim and upstream of this village, more mafic coarse-grained dark-green coloured facies corresponding to tonalite prevails (61 AE-45). Parts of them appear intensely altered and sometimes gathered in narrow stripes with marked cataclastic and diaftoritic deformations (61 AE-46). In the same zone fine-grained amphibolic leucogab-

bro bands are inserted and variously suffered diaftoritic modifications (61 AE-47).

Quartziferous diorite with biotite and hornblende, dark coloured, medium or coarse-grained tonalite analogous to the Darrah-i-Jim ones, form all the peripheral band of the western part of the pluton, from the apophysis cropping out south of Kalafghan as far as the isolated masses between the Farkhar Slates south of Astana Tepa as far the Khurmab valley (61 AE-73, -76,-84). To them, limited zones of microgranular aplogranodiorite with sometimes oriented texture (61 AE-83) seem more diffused in the innerst part of the mass.

South of Kalafghan, the leucogabbric microgranular facies seen near Darrah-i-Jim reappear. Here they clearly seem to form marginal facies of the mass, with a thickness of 70 to 100 m (61 AE-72). There are again, to a lesser extent, the phenomena of diaftoritic alteration (61 AE-74).

Penetrating the valleys deeply intersecting the pluton south-east of Kalafghan, near Zardaln Darrah, massive tonalite is also noticeable (61 AD-39, -47), forming isolated outcrops among the black slates (61 AD-46). Continuing through the Bula-i-Ailah valley there is a leucogranite with fine-grained biotite (61 AD-41) analogous to the one noticed upstream of Kashan.

North-eastwards, beyond the Moshad valley, the pluton suffers a marked variation of composition and lying that, as we shall see further on, seems to be accompanied by a certain difference in the correspondent values of absolute age. The pluton takes a narrow and elongated form, that becomes a band of a few hundreds of metres thick, between Halqa Jar Amphibolite eastward and Farkhar Slate westward. As this part of the intrusive mass appears at the margin of the surveyed area it seems possible that the dioritic band surveyed between the Farkhar Slate and the Halqa Jar Amphibolite near Sang Ab is only a great filonian apophysis of the mass itself, that developed further eastwards.

The same Sang Ab aphophysis is accompanied by a thick mylonitic band, the lithologic types of which will be described in a following chapter. The granular rocks prevailing consist of a fine-grained very sialic tonalite with biotite (61 AE-57) that peripherally passes to more mafic facies up to diorite rich in amphibole and with more marked and homogeneous grain (61 AE-58). The same dioritic type appears in form of filonian apophysis in the amphibolites south-east of Sang Ab.

In the northern part of the apophysis east of Kangurchi the tonalitic types seem to prevail though they are transformed by diaftoresis process (61 AE-64). The same fact occurs along the pluton and mainly round Kwaja Afghani and Tutak, where the tonalite has very marked grain increase in plagioclase and decrease the amphibole content until it disappears (61 AE-43).

Petrographical Features. — The most diffused rock in the central part of the pluton, corresponding to the south-western portion of the surveyed area is a coarse-grained hornblende tonalite with marked ipidiomorph granular texture and a biotite quartz diorite.

The prevailing petrographical feature is given by the abundant plagioclase, up to more than 60% in the total composition, given by an intensely zoned type changing composition from 50-52% from the central to the peripheral parts.

The central parts of andesinic or labradoritic composition seem to be very extended if compared to the peripheral rings with quickly decreasing content of An.

The cores generally appear very alterated, on the other hand the peripheral parts are progressively more limpid. Among cores and peripheral parts there is not, however, such a difference to suggest a continuity in the crystallization of the isomorph mixtures, as we can see in the most acid facies belonging to the north-eastern apophysis of the pluton. The texture of the rock is dominated by the idiomorphism and by the great size of the plagioclasic prisms, with the clearly anhedral interstitial filling of quartz and potash feldspar. Analogous result is given by the hornblende prisms, often in poikilitic concretions with labradoritic not geminated plagioclase and with biotite; both of them are euhedral and often very developed. Biotite also develops alone in chaotic lamellar groups, full in magnetitic interlamellar segregations. The amount of mafic components is about 15 to 20%.

In tonalite poor in hornblende and in quartziferous diorite the quantitative composition of the sialic minerals is mostly unchanged while biotite alone can reach the 20% of the whole composition. Plagioclase is andesinic or labradoritic with a maximum content An 55%. The zoning of plagioclase is much less marked than in the types just described and the peripheral oligoclasic rim very seldom appears.

On the other hand, there is a heterogenous composition causing spot-

ted very marked structures where, anyway, there is a variation of An content not above 10%. Here too the twinnings, that are generally complex, are very developed. The distribution of plagioclases is rather heterogeneous; besides the isolated prismatic fenocrystals there are small specimens with unitary composition, that are generally intertwisted or quite blastically superimposed. Also quartz is differentiated from the feldspathic groups in form of wide, often optically unitary areas, sometimes in form of ondulating extinction and recrystallized at the borders in thin microgranoblastic rows. Analogous paracrystalline deformations are noticed in biotite with large poikilitic laminae with intense red-brown colour. To these types we must add some peripheral leucogabbric facies having the highest basicity both in plagioclase composition, reaching the 58-60% An, and in the quite total lack of quartz.

The coloured minerals, comprising chlorite of late genesis in some cases reach the 80% of the total composition. The structure of these rocks is characterized by the prismatic stripe-shaped aspect of plagioclase placed also in fluidal orientation and including anehdral granules of hornblende.

A group of rather anomalous types is given by rocks of the aplit-granitic family, among which there are aplogranodiorites and leucogranites essentially made up or plagioclase, quartz and potash-feldspar, with a very reduced percentage in mafic elements among which are biotite and, very seldom, hornblende. In them plagioclase has the same high content in An formerly noticed in the dioritic types, that is andesine up to labradorite An 52%. The zoning phenomena of plagioclases appear very marked.

The calcic core has very developed geminations and is also accompanied by intense alterations with sericitic products or of incipient saussuritization, chiefly proceding along fracture planes. The peripheral part, with albitic to oligoclase composition, is generally limpid and lacking in geminations. Sometimes rings with decreasing content in An interpose; at times the passage is sharp and sodic plagioclase develops independently from the core, following a new crystallographic orientation.

Petrogenetical Considerations. — Jalmish pluton can be considered the product of magmatic late-Hercynian injections, placed along important lines of crustal weakness. The essential feature of the mass is the great va-

riety of mineralogic composition having repercussion in a genesis rather protracted, as the data of absolute age show.

To the genesis of the pluton a series of following magmatic injections that complexively changed in acid sense, contributed. In spite of the lack of data for a sure and detailed reconstruction, we can suggest the following evolutive sequence: tonalite with leucogabbric differentiates, quartz-plagioclasite and quartz diorite, aplogranodiorite, leucogranite.

As already observed, the common feature of a great number of these petrographical types is given by the very zoned structure of the plagioclases keeping a very calcic core, up to above 50% An, also the most acid facies.

A discontinuity between core and rim of these crystals has often been observed, as to suggest a long permanence of the calcic portions in a silicate bath with strong alkali tendence. It is probable that the original magma had tonalitic composition and that, in a very long intrusion period, an essentially plagioclasic crystalline phase was separated. Through subsequent reactivation movements of the crustal slots sheltering the intrusion, the residual liquids with granitic composition were ejected. They included the solid plagioclasic phase and variable quantities of iron-magnesium minerals. With a series of subsequent differentiations a magma with leucogranitic composition appears. In it the calcic cores of plagioclases are partially readsorbed, while on them the following coverings, with albitic or oligoclasic composition, increase also with independent crystallographic orientation.

During the latest intrusion the already solid crystals were partially deformed and fractured; as recognizable in the leucogranitic facies chiefly.

As to the quartz dioritic mass of Kakan, it must be considered genetically bount to the Jalmish pluton, but although it was described before, the relation on the ground between the two masses was not explained. The Alpine age deduced from the measure of absolute age of Kakan rocks is probably to ascribe to the cataclastic and dynamometamorphic modifications suffered by the last with the late dipping of the Upper Amu Darya Depression.

2.2. Kakan Quartz Diorite.

General Features. — It is an intrusive body lying between the Halqa Jar Amphibolite and the Farkhar Slates, cut by the Kokcha valley near the village of Kakan.

It is composed of quartz-plagioclasite with a little biotite and hornblende, affected at different degrees by cataclasis phenomena. The latter particularly developed along the eastern border of the mass, where there is a blastomylonitic zone up to 3 km thick. Some mylonitic lenses also exist in the central part of the pluton near Arqa Qeshlaq. Farkhar Slates form the partially conserved roof of the intrusive mass; the contact is rather sharp and with moderate effects of thermal metamorphism.

Field Observations. — The direction of the intrusive mass and its relationship with the Jalmish Tonalite are continuous; but there are also reasons suggesting the distinction of two masses also in the geological map.

First of all, the marked mechanical deformations with consequent mineralogic transformations undergone by Kakan diorite, do not allow a sure petrographic diagnosis, therefore it is difficult to compare them with Jalmish Tonalite. Then the two intrusive masses are divided by thick eolic deposits and by the Tertialry sediments of the Kokcha Formation extended eastward along a depression in concomitance with the present valleys of Hazara and Darayem. The measures of absolute age, moreover, while for Jalmish pluton are about 190 and 220 M.Y., in Kakan Quartz Diorite fall to 12 M.Y. (Desio, Ferrara & Tongiorgi, 1964).

The phenomenon could be ascribed to the late dynamometamorphic transformations suffered by the measured minerals, but it is not possible to deny a later age of the whole mass or of a part of it to a rejuvenation in Alpine phase.

Kakan pluton is deeply eroded only in correspondence with the Kokcha valley as elsewhere its cortical part crops out with large parts of the roof of black slates still conserved in correspondence with synclinal-shaped depression. The lithological type is given by quartz-plagioclasite with biotite and fine or medium-grained rather homogeneous hornblende affected everywhere, even if on different way, by strong cataclasis and alteration.

The latter essentially come into evidence with saussuritization and chloritization of biotite and give the rock a diffused white-greenish colour (61 AD-X, 61 AE-35, -37, -38).

Petrographical Features. — All the samples studied are characterized by intense mechanical deformations, by saussuritizations, transformations of the amphibole into biotite and consequent extended chloritization of this last. The original composition can be considered that of a quartz-plagioclasite with biotite and hornblende, with very abundant plagioclase and calcic core surrounded by a thin albitic oligoclasic rim. This last feature is similar to the one of Jalmish Tonalite even if, owing to the quite total saussuritisation of the plagioclases, it is not possible to value the limits of variability of the zoned crystals exactly. Near plagioclases there are potash-feldspar specimens, not more diffused than 2-3%.

Quartz is, on the other hand, abundant, about the 30% of the total composition, and placed in levels that are optically unitary with extremely undulating composition and with sharp limits, sometimes recrystallized in nests or microgranoblastic veins. So, the granular ipidiomorph structure is rather marked, because the feldspathic crystals, even if intensely altered, keep idiomorph prismatic borders, mainly where the albitic oligoclase margin is better developed.

The mafic components are, on the other hand, intensely deformed and dismembered, chiefly where they are more thickly included in the quartzous levels. Generally the contacts among quartz and the mafic components are given by shearing surfaces with a certain continuity and iso-orientation. Where they are more intense, the rock gradually looks like a cataclasite with oriented texture or, where a certain blastesis occurs, it becomes a blastomylonite with a gneissic appearance.

2.3. Naghz Darrah Tonalite.

General features. — The Naghz Darrah Tonalite constitutes a circumscribed quite round-shaped pluton wrapped by Halqa Jar Amphibolite and grading northwards to the more mafic facies of Muzung. In the central part, the pluton has a depression in which a conspicuous part of the am-

phibolite roof remained. It is crossed by a thick dyke system of pegmatite, granite and tonalite. The dyke suite widely develops also on the western side of the pluton; along the contact with the amphibolites.

The rock forming the pluton has variable composition from tonalitic to leuco-quartz-dioritic to leucogranitic.

FIELD OBSERVATIONS. — The highest part of the pluton lies up from the villages of Kalan, Sela-i-Khurd and Sela-i-Kalan. It has the shape of a massive relief ending in a ridge with E-W trend about 3000 m above sea level. The rock is a massive medium to coarse-grained tonalite with biotitic very developed flakes (61 AP-120, -121, -128).

This facies is uniform as far as the northern border of the mass where there is a transition to Muzung Gabbro. The southern part of the pluton itself has more complex and changeable facies and also a greater development of the dyke suite abundantly intruding into the body of the pluton. The south-west position of it has been studied along the path leading to the Zyarat-i-Kwaja pass, from the village of Talbuzanak. Here the principal magmatic mass is given by a medium-grained, green-grey coloured tonalite with garnet and epidote, and with sligtly oriented texture (61 AP-56). On it slots with north-east trend are noticeableffi they have dyke filling of quartziferous microgranodiorite with garnet and epidote (61 AP-58/I). On the described mass a system of later dykes about 5-7° wih E-W direction comes into evidence. A first generation of thin and tabular micropegmatitic quartzous-plagioclasic dykes, with muscovite and garnet, intersecated by thicker pegmatitic dykes, grading to normal granular facies is recognizable. The pegmatite contains microcline, garnet and irregular biotitic nests (61 AP-61). The granular rocks correspond to medium-grained tonalite with two micas, and slightly oriented texture, containing as additional elements garnet and epidote (61 AP-62). At the contact the amphibolite is intensely injected by quartzous-feldspatic veins (61 AP-64).

In some regions, mainly between Du Abi Yaftal and Darel and near the village of Langar, the amphibolite is wrapped in the granite in the shape of stratoid incluses that are particularly dark and thick, fine-grained with zoned texture and penetration of sialic material bed to bed.

Along the northern slope of the pass there are wide pegmatitic levels that seem to be contemporary with the principal tonalitic body (61 AP-65).

East of this zone, along the Darrah-i-Paseyel valley, the pluton is crossed by an amphibolitic band with intense filonian pegmatitic and microdioritic manifestations, beyond which the massive coarse-grained tonalite analogous to the one of the northern ridge crops out.

In the Palang Darrah valley we can see that these rocks contain stratoid bands up to 10 m thick of massive amphibolite (61 AP-131). At the south-east end of the pluton round the village of Bazgeran, amphibolite is crossed by thick dykes of pegmatite.

Petrographical Features. — The tonalitic mass of Naghz Darrah presents a rather complex composition both for the inner unhomogeneity, caused by digestion of country rock, and for the rich mainly pegmatitic filonian content.

The type representing the most common facies, mainly in the central less contaminated parts of the mass, corresponds to a medium-grained tonalite, and the mafic components with large size. The rock is composed of plagioclase (61-58%), quartz (20-25%) and mafic components (15-20%) among which biotite is prevailing over hornblende. The granular ipidiomorph structure is dominated by the idiomorphism of plagioclase prisms with andesine basic composition An_{43-40}, with developed complex and widely zoned twinning. Quartz appears at first deformed in paracrystalline phase, then partially recrystallized in microgranoblastic nests and veins. Biotite is partly primary, partly derives the transformation from hornblende, partly from the alteration of plagioclase, probably during the phase of mechanical transformation suffered by the rock.

The principal variation of these tonalitic types, recognizable on vast scale, is given by a diorite with analogous composition in which garnet and epidote appear up to the 8% on the total composition. Without change in the percentage of the other components, there is a structural variation, that is a general xenomorphism. Garnets and epidotes appear in prismatic granules rather dismembered but usually fresh, always associated with one another and mingled with the other mafic minerals, biotite, hornblende and titanite.

Some microdiorite facies representing the oldest filonian products included in the mass of epidotic-garnetiferous diorite have mineralogic composition analogous to the one of a true diorite. Markedly more acid dif-

ferentiations were recognized in the central and oriental part of the mass, where types in which potash feldspar is quantitatively equal to plagioclase (leucogranite) and quartz-dioritic types where plagioclase is as abundant as in the tonalite, but with more sialic composition (oligoclasic in association with a little microcline) appear.

The pegmatites crossing the Naghz Darrah mass in different phases reflect the dioritic character of the activity to which they are joined, but with a clear distinction in two types; a pegmatite rich in quartz and albite-oligoclase plagioclase with local late introduction of potash-feldspar; a garnetiferous pegmatite with smaller quantity of quartz, slightly more basic plagioclase and quartz in the normal crystallization order, without reciprocal concretions and with euhedral coarse-grained structure without excess unhomogeneity. Plagioclase is sometimes slightly zoned and formed in synkinematic conditions. Afterwards other deformations interested the rock, acting as intrusion way to alkali-potash solutions from which microcline crystals in fractures, and partial substitutions of muscovite on plagioclase were originated.

In the garnetiferous pegmatite, a more complex genesis can be seen. The crystallization begins with microgranular euhedral and graphic quartzous-plagioclasic intergrowings with scarce microcline followed by the components of pegmatitic size.

2.4. Muzung Gabbro.

General Features. — It is a considerable mass of gabbroidic rocks cropping out north of the tonalite pluton of Naghz Darrah, at the northern margin of the surveyed area. Diorite and gabbro seem to be the products of the same magmatic cycle with some transitional gabbro-dioritic facies present at the borders chiefly. Some large gabbro-dioritic lenses appear farther southwards, isolated in Halqa Jar Amphibolite.

On the whole, the gabbric mass appears to be composed of bands of different composition oriented sub-parallel to the margins. The gabbro shows passages to amphibolic gabbro at the contact with which there are also lenticular patches of crystalline limestone.

The name of the pluton comes from the village of Muzung lying about 21 km north of Faydzabad.

FIELD OBSERVATIONS. — As has already been said, the northern part of the Naghz Darrah pluton shows a quick passage to more basic types, with very changeable petrographical features, reflecting the unhomogeneities of pre-existing assimilated rocks. The facies made in this way, extend on a wider surface that the ones of the pluton itself, but not exactly measurable, because it is partially beyond the surveyed area.

The most diffused type is a gabbro rich in clyno-pyroxene (61 AP-115) grading to a medium-grained amphibolic gabbro, with slightly oriented texture (61 AP-116). In these rocks there are bands of dolomitic saccharoid white marble (61 AP-117 a) with prevailing E-W direction particularly developed round the village of Ert.

Here and there is a thick mingling of calcareous and amphibolic beds forming clearly schistose fine-grained, emerald green-coloured rocks (61 AP-119). At the contact with these calcareous relics the gabbric rocks increase in amphiboles assuming an intense green colour and a greater schistose orientation. Often there is an irregular distribution of the sialic components gathering in fading veins and trails (61 AP-118).

In the mountains north of Ert among the granular rocks the diallage gabbro is prevailing. It have interpositions of thick amphibolitic bands, analogous to the ones above described, and other interpositions of massive fine-grained thick and heavy grey-green-coloured olivine gabbro (61 AP-117). These type seem to prevail in the central part of the mass, beyond the northern limit of the surveyed zone. At the south-eastern margin of the mass, that is north-east of Sela-i-Kalan, some big gabbro-dioritic lenses appear isolated in Halqa Jar Amphibolite. They are mainly transformed by a low degree metamorphism into rocks with actinolite and epidote keeping the original massive texture, that are sometimes talcose, sometimes with incipient serpentinization (61 AP-123, -124).

Another big amphibolic gabbro lense appears south of Naghz Darrah, near the village of Bazgeran. It is grading to biotitic-amphibolic gneiss and gneiss with relics of white saccharoid marble.

PETROGRAPHICAL FEATURES. — The prevailing petrographical type is represented by a medium-grained diallage-gabbro with ipidiomorph granu-

lar structure, quite entirely made up with plagioclase and monocline pyroxene, with a high percentage of alteration products of the pyroxenes. Plagioclase is made up of labradorite 56-60% An in thickly compenetrating crystals partially developed on cleavage faces that have marked polysynthetic geminations, generally with unitary compositions, sometimes with slightly more calcic cores. This plagioclasic aggregate includes pyroxene prisms strongly corresponding with diallage markedly corroded and uralitized both inside and outside.

This transformation is accompanied with the segregation of magnetite sometimes substituting entire crystals, assuming roundish or lobed shape, round which an uralitic rim of microfibrous actinolite grown in normal direction with the border of the magnetic granule remains.

In some samples olivine is added to piroxenes, in a quantity up to 10% of the total composition, while the labradorite content is about 40%. In them pyroxene is generally formed by augite prisms with brown-rose colour, where the uralitization is less developed than in the mentioned types. The magnetitic segregations are, on the contrary, equally developed both inside pyroxene crystals, in form of clots and nodules, and in interstitial position between them and the plagioclasic aggregate; in this case they are surrounded by a microfibrous rim of uncertain determination, but probably amphibolic. Olivine has a border made of marked crowns of fibrous actinolite, mainly developed at the contact with feldspathic specimens. A marked clastesis with clearly postcrystalline origin is developed on both types of gabbros.

In correspondence with intercalations of marble beds in the gabbro, this latter assumes an amphibolic facies where porphyroblastic crystals made of green hornblende are recognizable. They are totally substituted by actinolitic felts with beginning of subsequent serpentinization. The plagioclase of these rocks are totally transformed into a saussuritic aggregate in which needles and fibrous bundles of actinolitic amphibole mingle.

To these metamorphic transformations, also a partially schistose texture is joined and reaches the contact zone with the marble. The contact is often accopanied with bands of skarn prevailingly made up of amphibole, pyroxene, calcite and titanite with chlorite and antigorite as secondary minerals. The marble is markedly saccharoid and pure, with scarce granules of titanite and scapolite.

2.5. Petrogenetic Considerations on the Plutonic Bodies of Muzung and Naghz Darrah.

As has been above described, the igneous rocks of Muzung and Naghz Darrah, can be considered as different facies of a single igneous mass, placed into the amphibolitic formation of Halqa Jar.

A continuous change of composition can be seen from the mafic to the sialic types, grading from gabbro to tonalite, to quartz diorite, to leucogranite accompanied by different pegmatitic phases. Into the gabbric mass synthexis phenomena are noticeable. They are caused by the assimilation of calcareous dolomitic rocks. Such transformations are particularly evident in the zone of Ert, where amphibolic-pyroxenic calcphyres develop round the carbonatic relics while the gabbric mass enriches in amphibole, assuming somewhere a very marked grain. No contact phenomena occur between gabbro and amphibolite, and neither between gabbro and biotitic gneiss. On the other hand, wide synthexis processes are noticeable along the contact zone between Naghz Darrah Tonalite and the amphibolite. The peripheral quartz-dioritic band with garnet and epidote, described near Zyarat-i-Kwaja, derives its anomalous mineralogic composition from the assimilation of amphibolitic rocks. Semidigested inclusions with amphibolic nature are present along the southern front of the tonalitic mass and inside it in the Langar zone. Transformations ascribable to the regional metamorphism are not particularly marked and become more and more intense from west to east.

The conditions of high-grade metamorphism that gave rise to the nearby Faydzabad Gneiss are lacking together with the ones typical of the amphibolic country rock. On the contrary, there are epimetamorphic modifications, mainly at the eastern margin of the mass, characterized by schistous orientations of some contact surfaces, by more or less complete transformations of pyroxene into amphibole and by formation of serpentine.

This facies is typical and belongs to the green schists, where, coming from rocks with low silica content, serpentine forms a stable phase near actinolite and epidote, as we can notice in the lenses of actinolitic schists described in the zone upstream of Sela-i-Kalan.

According to these considerations we can argue that the gabbro-dioritic mass had magmatic origin and was intruded in a partially unconfor-

mable form, under conditions of tectonic stability, into Halqa Jar amphibolitic formation. Subsequently the plutonic mass was interested by green schist metamorphism of Alpine age. Magma suffered a certain metamorphic differentiation with fractional crystallization to which a series of continuous reactions of plagioclase from labradorite to albite-oligoclase and of discontinuous olivine-clynopyroxene-amphibole reactions corresponds.

The mafic portion intruded into the central part is widely including the country rocks. To these sintexis phenomena the structure in bands of different composition of Muzung gabbric mass is related. Once stated that the quartz-dioritic facies of the southern margin are caused by assimilation phenomena of amphibolite, the original facies is represented by tonalite, at the northern margin of the mass, and by filonian leucogranitic to pegmatitic facies in the central part. To the later ones the introduction of alkali patches with potassic character was joined. They probably corresponds to the final remainder of the crystallization and are explanable as autometasomatism phenomena.

2.6. Baharak Granodiorite

General Features. — Baharak Granodiorite crops out north-east of the village of Baharak in the form of a wide mass of acid granular rocks belonging to the aplitgranitic family. It is characterized by a sharp contact with the black slates westwards and by the development of thick migmatitic series eastwards.

Most of the mass consists of two micas bearing quartz plagioclasite and by leucogranite; at the contact with the black slates, porphyroid facies with prevailing leucogranitic composition are developed.

South of the Kokcha river, the mass grades into a very leucocrate apophysis mainly made up of aplite and aplitic granite.

Field Observations. — The wide fluvio-glacial valley of Baharak is closed at the east end by a rough range of granitic rocks up to 4200 m above sea level in Koh-i-Hazar-Chashma. It forms the core of the migmatitic zone extended between the Warduj and the Zardew valleys, stretching north-east as far as Lake Shiwa zone.

As described in a preliminary note (DESIO, MARTINA & PASQUARÉ, 1964), the plutonic mass is characterized by a sharp contact affected by thermic metamorphism with the black slates on the western side, and by a wide migmatitic band along the eastern one. North of the Zardew river, the intrusive mass has the shape of a wide pluton with a well preserved vault, mainly on the western side, where it slowly dips under the black slates roof. On the opposite side, along the Zardew valley, high steep walls, with sharp peaks and ridges, mark the contact of the intrusive mass with its migmatitic mantle very bare. Where it is crossed by the Zardew, near Malang Ab, the body of the pluton thins to become 2-3 km large, progressively lessening southward in form of a narrow apophysis and ending on the left side of the Warduj valley. In this zone is substituted, on the western side, by a wider facies of gneissic deformation in which the marks of the original intrusive structure are very evident.

The rock of the axial part of the pluton is made up of a massive, fine-grained, quartziferous two micas plagioclasite (61 AP-67), that is light and homogeneous coloured, associated to massive, fine-grained, more acid masses, corresponding to leucogranite (61 AP-157).

It prevails with constant composition along all the ridge of Koh-i-Hazar Chashma, along the Koh-i-Yabad Darrah peaks, falling perpendicularly to the Zardew valley and to the Gulestan valley, that deeply cuts the pluton on its north-western side.

In different parts, proceeding towards the black slates contact, it is noticeable a marked transition to porphyric types. At first it occurs with feldspathic rather corroded phenocrystals, then with big euhedral prisms up to many centimetres in size. The prevailing composition is that of leucogranite with biotite (61 AP-68). In the magmatic mass there are also semi-digested inclusions of blackish or grey-green coloured arenaceous schists, some times filled with feldspathic phenocrystals of neoformation, belonging to the black slates that form the roof of the pluton. Along a band some tens of metres thick, at the contact with the pluton, these turn them into very hard, splintery, iron-grey coloured cornubianite with cordierite and andalusite (61 AP-69). Upstream from Malang Ab, in the Wakh Sir valley, the intrusive mass largely undergoes an intense cataclasis from which laminated products, green-coloured for the presence of chlorite and attinote, derive. Wide parts of the rock are reduced to very hard, splintery, whitish, slightly

translucid granitic mylonite (61 AP-70). The cataclastic zone does not go further than the Zardew valley.

The southern apophysis of the pluton, on the contrary, clearly grades to massive light aplitic clearings, that are interrupted only by some nebulitic spots enriched in biotite (61 AP-83). The high mountains over the Warduj upstream from Dastuk and the greater part of the intrusive band crossing Koh-i-Rangan partition spur of the Warduj and Zardew valleys, are made up of this composition. On the spur there are also true massive, light-coloured fine and homogeneous-grained biotite granites (61 AP-81), insensibly grading to the above described aplite.

Petrographical Features. — It is a series of subsequent differentiations framed into the quartz plagioclasite-leucogranite-aplitgranite-aplite association. Common feature is the constant percentage in quartz between 30 and 33% of the total composition, coinciding with the medium content in quartz of the alkali granite. The plagioclase content changes from 57% of plagioclasites to 17-22% in the aplitic types, while their oligoclase-andesine composition An_{31-38} is rather stable. Alkali feldspar is completely lacking in many plagioclasites, that assume a mineralogical composition rather similar to very quartziferous tonalite. As they are types very poor in mafic minerals it is more suitable the comparison with trondhjemite, corresponding to alkali-calcic granodiorite.

In the aplitgranite, aplite and leucogranite, alkali feldspar is prevailing given by microcline, and microclin-perthite, accompanied by diffuse mirmekite rims of reaction with plagioclase.

The feldspars seem to have been simultaneously crystallized (or recrystallized); sometimes a slightly earlier crystallization of plagioclase is evident. The growth of plagioclase is so interrupted by alkali feldspar that often develops in form of sub-idiomorph crystals.

Leucogranite differentiates in a slightly superior percentage of alkali feldspar on plagioclase, while it is still tightly bound to granite for structural reason. Another common feature of the rocks in this group is given by the scarce mafic elements, generally represented by biotite, more seldom with associated muscovite. This one has clearly late, post-tectonic origin, probably for alteration of the feldspars under pneumatolitic actions. The quantity of micas is changeable from the 3 to 5% in the granitic-aplitic types, reaching the 10% in quartz plagioclasites.

Cataclasis phenomena are diffused everywhere, mainly in the granitic facies of Malang Ab apophysis. Lamination on the crystals scale seem to be later than the cataclastic phase, and, as they are accompanied by a certain degree of oriented recrystallization, they partially restore the previous deformations.

In the mylonitic and ultramylonitic types we noticed a opaque grounmass including splinters of different size of sialic elements: in decreasing order quartz, plagioclase, potash-feldspar.

Petrogenetical Considerations. — Baharak mass of granular sialic rocks is the most typical example of synkinematic metasomatic granitization in the crystalline complex of Central Badakhshan. Along the eastern side its genetic connection with the augen banded migmatitic gneiss of Kurkhu formation and with the nebulitic migmatitic gneiss of Tarang is certain. With regard to the latter formation it has been outlined that in the most developed migmatitic types palasome completely disappears while more or less extended masses with aplogranodioritic and leucogranodioritic composition appear. They are now and then joined by schistose biotitic beds made by imperfect transformation of palasome.

The petrographical affinity between these metatectic masses and many granular rocks of Baharak mass is evident. Such affinity is recognizable even in some details with uncertain genetic significance, as the great amount of albite-ala twins in the plagioclases of both formations.

The granitization phenomena widely and thickly diffused in the formations delimiting the mass eastward and southward are substituted, at least apparently, by a sharp contact with black slates characterized by marked but not much extended isothermic modifications of the slates. It is anyway rather difficult to state wether a migmatitic mass very moble and furnished with intrusive energy in its upper part was formed or the phenomena is just a selective metasomatose that stopped at the basal level of the black slates. The second hypothesis seems to be more probable, mostly considering the variations of composition existing into Baharak mass. It must be emphasized that the different facies of Baharak granular mass are placed in a coarse stratoid form, with the alkali-calcic terms, corresponding to quartz-plagioclasite, in inferior position; and the potash-alkali terms, with granit trend, in the upper part as far as the black slates contact. It

is explainable if we consider the basal part as made by the metasomatic transformation of the same initial products, that were probably intrusive and originated Tarang plagioclasic gneiss.

The upper part, on the contrary, presents some petrographical affinities with the sialic metasomatic portions of Kurkhu Gneiss, and it would attest the ultrametamorphic transformation of an essentially pelitic metasedimentary series. The principal petrographical evidence of Kurkhu Gneiss, that is the transformation of micas into sillimanite, corresponds to a characteristic feature of the granitization phenomenon in the sillimanite zone, that is in the sillimanite-almandine sub-facies. To this reaction a sensible remobilization of potash is joined and this explains the richness in microcline of all the peripheral facies belonging to the roof and the southern apophysis of the pluton.

2.7. Abu Abdal Granodiorite.

General Features. — Abu Abdal Granodiorite forms a concordant lenticular pluton inserted into Rabat Gneiss in the Kokcha valley near Abu Abdal as far as the village of Darrah-i-Khash, not far from Jurm, in a NNW — SSE direction. The prevailing rock, furnished with noticeable homogeneity of facies, is a massive, fine-grained aplo-granodiorite that is very fresh and lacks in tectonic deformations. At the borders of the pluton a migmatitic facies is developed in Rabat Gneiss. This facies is formed by intense injection phenomena bed to bed of sialic material in the gneiss, diffused up to one kilometre thick.

Field Observations. — South-east of Faydzabad, between Abu Abdal and Jurm, Rabat Gneiss, belonging to the eastern side of Faydzabad anticline, contains a narrow granodioritic pluton.

The pluton is strictly conformable with the gneiss and is accompanied by intense injections bed to bed of sialic material in the country rock, particularly developed in the northern part. The pluton is videly bare of its covering northward, mainly along the Kokcha incision, while in the central

part and in the southern one it is still partially covered by its roof of gneiss and marble along the Koh-i-Surkh-Koh.

The rock is everywhere homogeneous and massive, very fresh at the fracture, crossed by a thick net of diaclases. In the central and southern part, where the pluton body is more unitary, a very light fine-grained aplo-granodiorite poor in mica prevails (61 AP-104) and northwards it grades to a slightly more biotitic fine-grained facies (61 AP-49).

The dyke suite of the pluton is particularly diffused and well exposed along the right side of Kokcha, between the villages of Abu Abdal and Wular. There are many dykes of pegmatitic hornblende-granite, of granite with heterogeneous texture and nebulitic spots with biotite and amphibolite, of pegmatite with wide muscovite flakes. To them a more recent generation of pegmatitic tourmaline strips is joined. These intersect the above described dykes.

Near the village of Wular there is a laccolite of leucogranite very light-coloured, poor in mica, wiht diffused mafic hybridization zones (61 AP-29) and, in the peripheral part, some microgranitic strips.

Along the Kokcha valley, on the western side of the pluton, there are very thick injections bed to bed with transformation of the Rabat Gneiss into migmatitic gneiss on a band up to one kilometre thick. It is a migmatitic garnetiferous gneiss with large sialic bands (61 AP-47) that sometimes have the shape of real granitic or pegmatitic dykes. The sialic elements, mainly quartz, are scattered also as big amigdales and lenses grading to granitic gneiss and granite. The marble bands frequently inserted in the gneiss are transformed into calcphyres with phlogopite and hornblende with interposed biotitic beds (61 AP-48).

An analogous migmatitic band is along the eastern side of the pluton, south of Abu Abdal. Metasoma is mostly quartz-plagioclasic in form of thin stripes, at the contact with which schistose palasome forms biotitic and amphibolic beds (61 AP-160). Also amphibolic gneiss with beds rich in scapolite and uralitized pyroxene with quartzous feldspathic and plagioclase-biotitic bands are formed (61 AP-161).

The southern apophysis of the pluton has a facies with oriented texture, in form of biotitic granitic augen orthogneiss, and a sharp contact with calcphyre and paragneiss that show only sporadic quartzous feldspathic enrichments.

Petrographical Features. — The rocks of the Abu Abdal pluton are distinguished by their markedly leucocrate character, and the fine and regular grain that in the outcrop makes them similar to very sialic granite. On the contrary, they mostly correspond to aplogranodiorites composed of oligoclasic plagioclase $An_{17\text{-}22}$ up to 57%, of quartz for 27-30%, and of a smaller quantity of potash-feldspar and scarce biotite together with muscovite derived from transformation of the feldspars.

The ipidiomorph granular structure shows a clear idiomorphism of plagioclase, followed in different crystallization phases, by potash-feldspar and quartz. Then there is a rather marked pneumatholisis with growth of pseudomorph muscovite on the feldspars or, for a smaller part, on their crystalline planes. This phenomenon seems to happen in synkinematic conditions, the same conditions that interested the other components with fracture deformations. To them, marked cataclastic effects due to a late tectonic phase, are overlain.

The same conditions occur in the leucogranites of Wular laccolite. They are distinguished by a greater content of potash-feldspar (more than 1/3 on all the feldspars) as the composition of plagioclase becomes more and more calcic, up to An_{29}. Unfortunately, samples able to give a more complete petrographical documentation are lacking among the filonian forms composing the pluton.

Petrogenetical Considerations. — Abu Abdal Granodiorite forms an igneous body of « mixed » origin, of which the greater part is ascribable to a magmatic process.

To uphold the magmatic origin of the greater part of the pluton, that is of the whole mass of granodiorite, we enumerate the following data:

a) the structural relations with the country rock show a forced magmatic settling into the gneiss;
b) the rock of the pluton is everywhere characterized by a very homogeneous composition corresponding to an aplogranodiorite;
c) in the mass itself, the marks of a substitution of pre-existing rocks or of selective fusion of them are absent, as the encasing gneiss is characterized by thick injections bed to bed;
d) the southern part of the pluton presents a rock with aplogranitic com-

position characterized by a gneissic orientation of the components, clearly produced in phase of paracrystalline stress.

It is interesting to notice that the injection gneiss of the peripheral band is characterized by more calcic plagioclases than the ones of the aplogranodioritic contexture. There is, on the other hand, a certain relation between the composition of the sialic bands of these gneiss and the leucogranitic dyke facies present in the Wular zone mainly containing more calcic plagioclases. Injection gneiss and peripheral filonian phenomena, on the one hand, homogeneous granitic rocks on the other, seem to be product of two distinct phases of a mixed process of granitization and magmatic injection. We consider the intrusion of aplogranodioritic magma as preceded by the rising of alkaline fluids along the line of tectonic weakness under stress. Such phenomena looks like a metasomatic granitization quickly stopped by the going up of the lower magmatic mass. It enables us to explain the great development of the migmatitic encasing gneiss, hardly ascribable to the simple effect of peripheral magmatic injection of a modest and limited pluton as Abu Abdal aplogranodiorite.

3. MYLONITE BELTS.

All the eastern margin of the Jalmish and Kakan pluton is characterized by a great development of cataclasis and mylonisis phenomena, the products of which are placed in bands and lenses conformable with the structural trends of the plutons and with their contacts.

Among these rocks, the ones coming from the deformation of the dioritic and granodioritic rocks of the plutons, and chiefly of Kakan pluton, are prevailing. This last appears divided from Halqa Jar Amphibolite by a cataclasite band about 1 to 3 km thick, and inside the pluton itself long mylonitic lenses appear. Farther southward, Sang Ab apophysis of the Jalmish pluton appears intensely cataclastic up to mylonitic along all the external margin of black slates. Also other parts of the pluton, between the valleys of Wakhshi and Darayem, seem to be interested by analogous mechanical deformations, in irregular and discontinuous, but very diffused way.

The band of cataclastic rocks coming from Kakan Quartz Diorite, was

distinguished with the name of Petwan Blastomylonite. Also on the ground of its genetical bound with the granular rocks of the pluton is clearly recognizable. It keeps also the same composition with a superimposed blastomylonitic texture. They are rocks with the composition of quartz diorite with biotite and hornblende, suffering an intense clastesis accompanied by saussuritic transformations of the feldspar and by following blastesis of quartz. At different degrees they suffered a fluidal constipation of the more markedly mylonitic beds round the less deformed quartzous or feldspathic cores conserved as phenocrstals with blastic eyes.

Near this blastomylonitic quartz-diorite (61 AE-36, -37, -38, -41), some bands more intensely deformed, darker coloured, with rougher and more compact look are distinguishable on the ground, mainly in Kokcha valley and north of it near Arqa Qeshlaq. They are mylonites very fine-grained, hard and splintery if fractured, made up of a criptocrystalline mass, mostly quartzous, mingled with saussuritization products, including a few iso-oriented strip-shaped quartz-feldspathic relics (61 AE-42).

In the southern part of Petwan Blastomylonite some tectonic lenses coming from amphibolite and biotitic paragneiss are inserted. Most of them could be cartographed near Petwan.

The blastomylonitic band cropping out north of Sang Ab has the same petrographical features described for Petwan Blastomylonite (61 AE-53). In this case too, its derivation from Jalmish Tonalite is sure. In it, however, the intercalations of biotitic paragneiss and rather fresh staurolite gneiss sometimes without mechanical deformations are very frequent. Most of these intercalations were observed west of the village of Kangurchi.

The same gneissic bands go on northwards; at first as very thin lenses at the margin of the dioritic mass, then with greater dimentions, mainly in the Teskhan valley, near Kwaja Afghani. Here also a biotitic gneiss with cordierite was noticed (61 AE-44). Both this last and the staurolite gneiss noticed east of Kangurchi are two petrographical types unknown in the metamorphic series of the Faydzabad and Baharak regions, so they must be considered as belonging to the Lower Paleozoic or Archeozoic base of the structural zone of Northern Pamir, where the granodioritic and quartz-dioritic Hercynian intrusions, of which Jalmish pluton is one of the farther southern specimens, took place.

D. DATA ON THE ABSOLUTE AGE OF SOME PLUTONIC AND METAMORPHIC ROCKS

The geological researchs in the plutonic and volcanic areas are substantially facilitated by the determinations of absolute age of some minerals (micas) of the rock samples. During the geological survey in Central Badakhshan we collected some rock specimens proper for these kind of determinations. The specimens were examined in the Laboratory of Nuclear Geology of the University of Pisa by E. TONGIORGI and G. FERRARA and submitted to the age determination by Rb/Sr method (DESIO, TONGIORGI & FERRARA, 1964).

The laminae of biotite and muscovite were separated and purified as described by JÄGER (1960). The rubidium and strontium contents were determined through isotopic diluition by means of an « Atlas » type CH_4 mass spectrometer provided with an electron multiplier. For the rubidium decay constant, a value of $1.47 \times 10^{-11} a^{-1}$ was employed. The error in the determinations of total rubidium and strontium is ± 3.5% and depends on the ratio $\frac{Sr\ 87\ rd}{Sr\ 87\ tot}$, being greater when this ratio is near 0.1. In this case, the precision of the measurements is ± 10%. The ages having a $\frac{Sr\ 87\ rd}{Sr\ 87\ tot}$ ratio less than 0.1 are reported in brackets and are to be considered as having a merely indicatory value.

A standard sample of biotite (Bern 4B) was used for control (Rb 592 ppm; Sr^{tot} 2.57 ppm; Sr^{87} rd 0.045 ppm).

In Table 3 are reported the essential data concerning the samples. As a basis of reference to the geological age of the dating in years POLEVAYA's table (1960) was employed [1]. On the fig. 29 the location of the samples examined are indicated.

(1) There are some discrepancies between the nomenclature of the rocks in the tables and those described in the Petrographic appendix. These discrepancies depend from the fact that two ore more samples collected in the same locality were submitted one to the petrographic investigation, another to the determination of the age.

3 - Age of some plutonic and metamorphic rocks of Hindu Kush and Badakhshan.

number	Locality	Latitude and Longitude	Rock type	Petrographic features	Occurrence	Rb tot ppm	Sr comm ppm	Sr^{87} rad ppm	Sr^{87} rad / ^{87}tot	Age (million years)	Group
	2	3	4	5	6	7	8	9	10	11	12
74	Between Jalmish and Ghandak (Hindu Kush)	35°08'00"N 68°00'30"E	Mafic granodiorite	The rock is similar in texture and composition to specimen 61 AD-71; it contains a little micropegmatite of deuteric origin.	Axial batholith West Hindu Kush	500	7.79	0.451	0.45	216	
71	Between Tolemo-i-Bali and Jalmish (Hindu Kush)	35°11'45"N 67°58'30"E	Mafic granodiorite	The mafic character is given by the presence of a large quantity of biotite and amphibole and by the calcic composition of plagioclase.	Axial batholith West Hindu Kush	575	8.03	0.515	0.48	214	I
75	Between Jalmish and Ghandak (Hindu Kush)	35°06'30"N 68°01'30"E	Tonalite	The essential components are: saussuritized plagioclase, quartz, hornblende and biotite. The quartz, abundant, occurs in granoblastic aggregates.	Axial batholith West Hindu Kush	420	3,16	0.369	0.63	210	Low[er] Trias[sic]
45	South of Darrah-i-Jim	36°42'50"N 70°07'09"E	Mafic granodiorite	Biotite-amphibole granodiorite, with zoned calcic plagioclase (An_{65-50}).	Bagh-i-Turk pluton	528	10.95	0.470	0.38	213	
32	Near the bridge of Darrah Sah Baba (Kishem)	36°42'40"N 70°09'58"E	Granodiorite	Biotite-granodiorite, showing moderate dynamic deformations.	Bagh-i-Turk pluton	606	11.10	0.529	0.40	209	

3 (*contd.*)

	2	3	4	5	6	7	8	9	10	11	1
57	Small valley SE of Sang Ab	36°40'31"N 70°12'08"E	Granodiorite	Biotite-amphibole granodiorite with typical hypidiomorphic texture. The hornblende is partly replaced by biotite.	Narrow and elongated pluton of Sang Ab	506	10.90	0.392	0.33	186	
84	Near Kashan	36°35'41"N 69°55'31"E	Foliated tonalite	The foliation is due to the parallel arrangement of mafic minerals (hornblende and biotite). The rock contains a little potash-feldspar.	Kashan pluton	257	17.44	0.199	0.14	185	I Upp Tria
						521	24.66	0.402	0.19	185	
33	Near Kashan	36°35'32"N 69°55'09"E	Granodiorite	Biotite-granodiorite. The plagioclase is corroded by the potash-feldspar and myrmekite is developed.	Kashan pluton						
120	Between Sahid Darrah and Kalar	37°17'13"N 70°35'45"E	Granodiorite	Biotite-amphibole granodiorite with incipient metamorphic texture, containing abundant epidote, chiefly clinozoisite, in well developed crystals.	Naghz Darrah pluton	432	5.85	0.245	0.37	135	
128	Upstream from Sela-i-Kadan	37°16'42"N 70°40'01"E	Tonalite	Biotite-amphibole tonalite, rich in quartz. Some epidote is present.	Naghz Darrah pluton	354	10.87	0.195	0.20	132	II Upp Jura
43	Near Kwaja Afghani	36°53'10"N 70°14'30"E	Leucotonalite	The rock has the same content of dark minerals as a granodiorite. Potash feldspar is absent and the essential minerals are: andesine-labradorite, quartz and biotite. The texture is partly metamorphic.	Kwaja Afghani pluton	512	8.38	0.275	0.32	129	
						394	9.40	0.209	0.24	127	

3 (*contd.*)

	2	3	4	5	6	7	8	9	10	11	12
-19b	Zebak	36°31'35"N 71°20'54"E	Cataclastic granodiorite	Biotite granodiorite containing, as minor component, hornblende. A rather strong deformation is revealed by protoclastic as well as by subsequent fracturing and granulation.	Small stock	429	11.25	0.170	0.18	93	IV Upp Cret ceou
-19a	At the back of Zebak	36°30'35"N 72°20'54"E				525	19.50	0.189	0.12	86	
-68	At the pass west of Wakh Sir	37°03'47"N 70°55'14"E	Adamellite	Oligoclase microcline-perthite, quartz and biotite are the essential minerals. Coarse feldspar crystals are present as phenocryst.	Baharak pluton	882	5.51	0.118	0.23	32	V Olig cen
-16	Little upstream from Deh Qalat	36°38'00"N 71°07'30"E	Migmatitic gneiss	Dark plagioclase-biotite gneiss lit-par-lit injected by quartz-plagioclase material.	Migmatite belt of (around) Baharak pluton	794	9.07	0.0944	0.13	28.5	
-17/25	Lake Shiwa	37°24'45"N 71°20'47"E	Blastomylonitic gneiss	Leucocratic blastomylonitic gneiss containing coarse white mica (partly derived from biotite) flakes and some fractured garnet granoblasts.	Transitional zone between igneous and migmatitic rocks of Shiwa	652	5.68	0.0618	0.13	22.7	VI Mioc
-17/19	Lake Shiwa	37°24'35"N 71°21'42"E	Pegmatite mylonite	Many porphyroclasts of feldspar in a pseudoschistose matrix, composed essentially of recrystallized quartz. Tourmaline and garnet are also present.	Strip within granitoid gneiss	1154	7.67	0.094	0.15	19.5	

3 (*contd.*)

	2	3	4	5	6	7	8	9	10	11	12
-H	Abu Abdal	37°04'13"N 70°43'35"E	Granite	Oligoclase, microperthite and quartz are present as porphyroblasts and compose too the fine-grained groundmass. Biotite and titanite are rather abundant.	Small stock	953	3.41	0.066	0.22	16.7	
17/3	Lake Shiwa	37°23'11"N 71°23'13"E	Biotite-garnet-gneiss	Dark migmatic gneiss, rich in biotite and containing a little garnet, showing a distinct separation into dark and light parallel layers. The sialic components, among which myrmekite is abundant, make also small eyes.	Band in migmatite	668	7.09	0.0452	0.084	16.2	V Mioc
18	From the landslide east of Ardar	36°58'00"N 70°56'40"E	Gneiss granite	Equigranular, medium-grained, foliated rock of granitic composition, containing biotite and muscovite as isolated flakes. Allanite and sillimanite are present.	Pluton	1431	4.81	0,093	0.22	15.6	
13	Warduj valley, 5 km upstream from Chakaran	36°51'36"N 71°03'57"E	Gneiss granite	Slight by cataclastic granite gneiss with crystalloblastic texture. The rock contains, besides biotite, some garnet and sillimanite. Garnet and biotite are partly transformed into white mica and chlorite.	Migmatitic belt of Baharak pluton	633	5.24	0,0353	0.09	13.4	
X	Kokcha valley, below Kakan	37°12'58"N 70°19'20"E	Granodiorite	Medium-grained biotite-amphibole granodiorite with hypidiomorphic texture. Plagioclase and biotite are strongly altered.	Small stock	367	4.21	0.018	0.06	12	

Summarizing the essential geological data of the table we obtain the following scheme:

I. Lower Triassic:		
(Late Hercynian)	*Mafic granodiorite*	Axial batholith of the Hindu Kush.
(Late Hercynian)	*Tonalite*	Axial batholith of the Hindu Kush.
(Late Hercynian)	*Mafic granodiorite*	Bagh-i-Turk pluton (Darrah-i-Jim and Darrah Sah Baba)
(Late Hercynian)	*Granodiorite*	Bagh-i-Turk pluton (Darrah-i-Jim and Darrah Sah Baba)
II. Upper Triassic:		
(Early Cimmerian)	*Granodiorite*	Sang Ab pluton
(Early Cimmerian)	*Foliated tonalite*	Kashan pluton
(Early Cimmerian)	*Granodiorite*	Kashan pluton
III. Upper Jurassic		
(Cimmerian)	*Granodiorite*	Naghz Darrah pluton
(Cimmerian)	*Tonalite*	Naghz Darrah pluton
(Cimmerian)	*Leucotonalite*	Kwaia Afghani pluton
IV. Upper Cretaceous:		
(Early Alpine)	*Cataclastic granodiorite*	Zebak stock
V. Oligocene:		
(Alpine)	*Adamellite*	Baharak pluton
(Alpine)	*Migmatic gneiss*	Migmatite belt around Baharak pluton
VI. Miocene:		
(Alpine)	*Blastomylonitic gneiss*	Lake Shiwa
(Alpine)	*Pegmatite mylonite*	Lake Shiwa
(Alpine)	*Biotite-garnet gneiss*	Abu Abdad stock
(Alpine)	*Granite*	East of Ardar
(Alpine)	*Granite gneiss*	Migmatitic belt of Baharak pluton
(Alpine)	*Granodiorite*	Kakan stock

The six groups can, in turn, be referred to three orogenetic cycles that is:

a) Hercynian Orogeny : I group;
b) Cimmerian Orogeny : II and III groups;
c) Alpine Orogeny : IV, V and VI groups.

This grouping of plutonic and metamorphic rocks and probably also of the plutonic bodies, is, at least to a certain extent, mirrored in the topographic distribution of the various outcrops. It can be observed in fact that proceeding from west to east, the plutonites belonging to the oldest cycles are replaced generally by those of the youngest cycle, at least up to the Jurm line.

The topographic succession following this order in Central Badakhshan is shown below (Fig. 28):

a) Kashan pluton (granodiorite and tonalite) = Upper Triassic,
b) Sang Ab pluton (granodiorite) = Upper Triassic,
c) Kwaia Afghani pluton (leucotonalite) = Upper Jurassic,
d) Naghz Darrah pluton (granodiorite/tonalite) = Upper Jurassic,
e) Abu Abdal stock (granite) = Miocene.

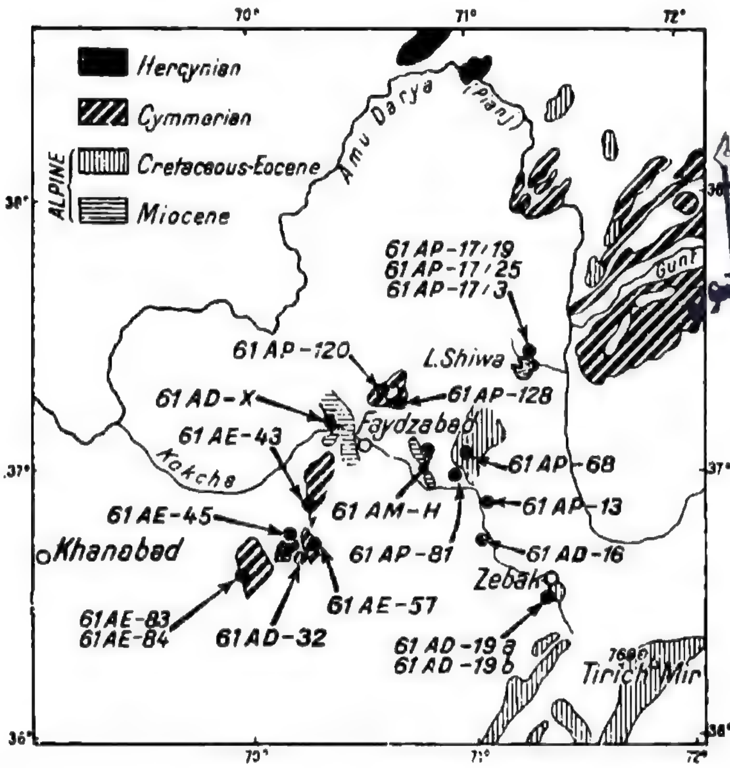

Fig. 28 - Location of the samples dated by Rb/Sr method in Badakhshan.

The Lower Triassic Bagh-i-Turk pluton (mafic granodiorite and granodiorite) appears to be interposed between plutons a) and b) of Upper Triassic age, but the relationships between the two plutonic bodies are not clear. It seems, however, that an older plutonite of the late Hercynian cycle is interposed between two plutonic bodies of the Early Cimmerian cycle, while the Kakan stock (granodiorite) of Miocene age, belonging to the Alpine cycle, is interposed between two plutons of the Upper Jurassic cycle. The topographic succession described above is not, therefore, typical.

Furthermore, to the east of the Jurm line, Oligocene plutonites are exposed belonging to the Baharak pluton which, as far as age is concerned, do not correspond to any plutonic bodies present in the studied area. The same thing happens also farther to the east where the stock (cataclastic granodiorite) of Upper Cretaceous age does not correspond to any plutons exposed in the area investigated.

The topographic distribution of the plutonites from the oldest to the youngest proceeding from west to east is admissible if we take into consideration that in Central Badakhshan the continuation of the Pamir tectonic zones is present (DESIO et al., 1964 b). In the latter region, proceeding from north (North Pamir) to south (Central and South-Eastern Pamir) the oldest plutonites (Hercynian) are replaced by the youngest (Alpine), although there are remarkable exceptions caused by tectonic dislocations. In the area studied, the north to south distribution of the Pamir outcrops becomes a west to east succession on account of the change in trend of the various tectonic units proceeding from Pamir to Badakhshan. It is also worth mentioning that Badakhshan is tectonically much more dislocated than Pamir as will see later.

E. SUMMARY OF THE MAGMATIC AND METAMORPHIC PROCESSES IN CENTRAL BADAKHSHAN

Central Badakhshan can be divided both on the structural magmatic and metamorphic points of view, into three great units:

a) western zone, of late-Hercynian plutonism;
b) central zone, of sinorogenic Hercynian granitization and Cimmerian plutonism;
c) eastern zone, of sinorogenic Alpidic granitization.

Such subdivision exactly reflects the orogenetic evolution of the region, the axis of which suffered a migration from west to east, as new tectogens rose, joined and strengthened to form the imposing and, from some aspect, peculiar lithospheric complex of Pamir.

The mentioned zones are limited by deep fractures and fault boundles with N-S trend, connected to the ones of Pamir through a marked bent deflection toward north-east (DESIO, 1964, 1965). Particularly are here recognisable the zones corresponding to Northern and Central Pamir, divided from the thick mylonitic band lying west of Faydzabad and east of Kishem. More detailed explanations on this subject will be given in the chapter about the tectonic structure of the region (page 330).

The metamorphic evolution of Central Badakhshan began with the transformation in meso and epizonal environment of the pelitic, arenaceous and calcareous-dolomitic sediments that filled the wide bottom of the Hercynian geosyncline limited on the oceanic side by a continental mass corresponding to the thick metamorphic plate of South-western Pamir (Figs. 29 and 30). The deepest transformations occured in correspondence with the central zone, where the kinzigitic formation of Faydzabad Gneiss took origin. In the granulite facies, the kinzigitic mass became a seat of incipient, even though not complete, anatexis, and of mobilization of granitic products that were injected in concordance in the gneisses with decreasing intensity from the « focus » of granitization coinciding (or underlying) with the deepest core of the formation. The kinzigitic formation probably stretched farther eastwards as far as the Baharak zone, were the following Alpidic metamorphism turned it into the Kurkhu polymetamorphic gneiss.

In the western part, that is round Kishem, rocks of high thermal, probably Hercynian metamorphism, among which cordierite gneiss and staurolite one, are found as isolated blades into the blastomylonitic bands at the margin of Jalmish pluton.

In the Baharak zone, above the mesozonal metamorphism develops on a pile of about 5000 m of sediments, among which is argillite, sandstone, marl, limestone, dolomitic limestone, tuff, and probably basic lava. The distribution of sediments shows a deepening of the basin from west to east, that is from the Kishem zone, that will be the seat of acid post-orogenic magmatism, as far as the Baharak zone where the prevailing calcareous and dolomitic sedimentation with pelitic intervals will go on until the Upper Jurassic.

Basic eruptions occurred in the zone north of Faydzabad, probably as basaltic sills with the relative pyroclastic products. These different original conditions brough to different metamorphism products, among which essentially fine biotitic-garnetiferous gneiss in correspondence with pelitic-psammitic sediments; amphibolite in correspondence with volcanic products, marble with phlogopite in the calcareous-dolomitic zones, biotitic schists and quartz in the argillites and siltites intercalated to the carbonatic rocks.

The mineralogical associations of regional metamorphism, are, on the whole, in the almandine-amphibolite facies for all the metamorphic forma-

tions of Faydzabad, Kurkhu and Tarang included; as the calcareous-dolomitic formations and the black slates of the zone north of Baharak show not so well determined mineralogical associations, ascribable to the green schists facies.

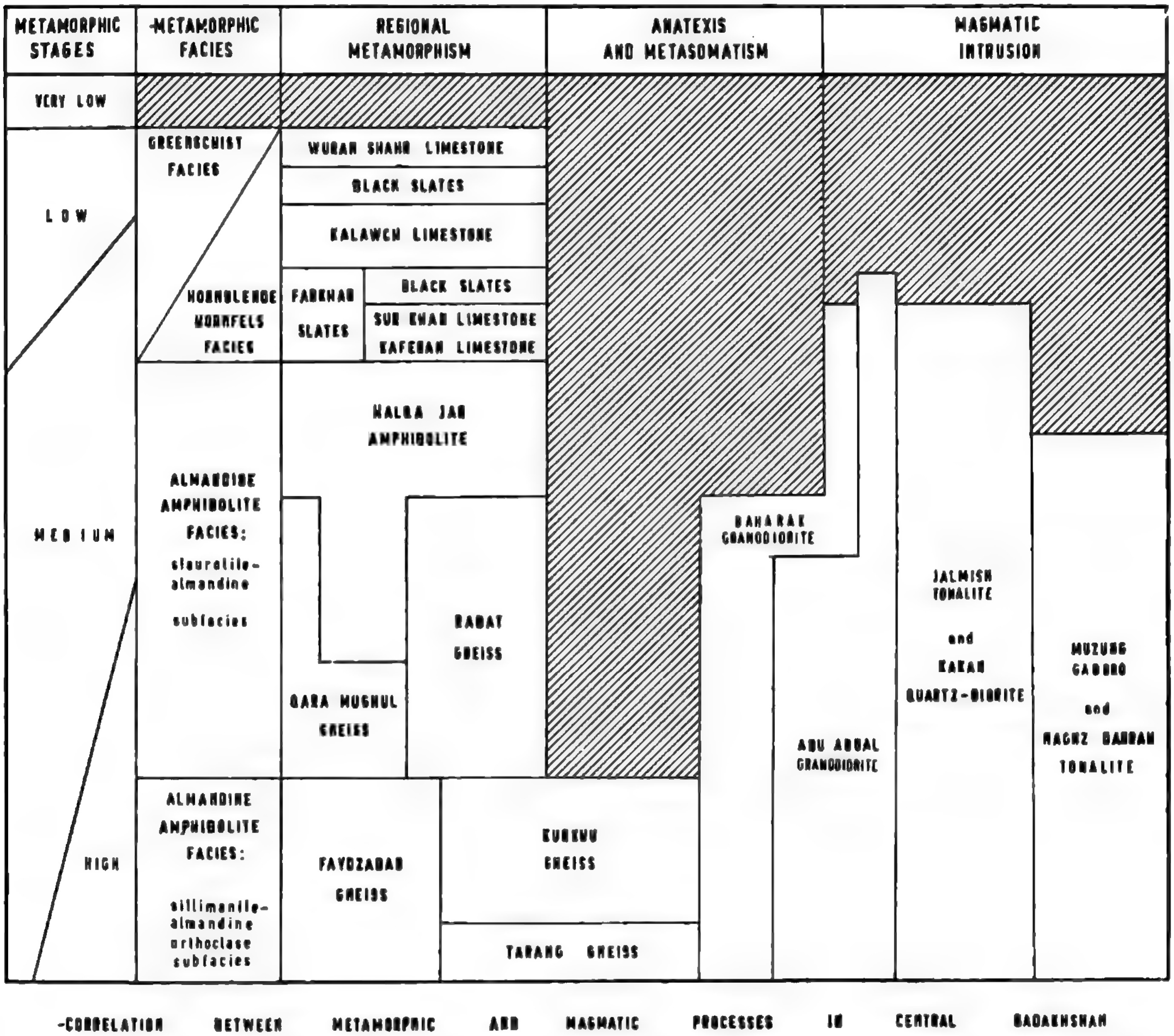

Fig. 29 - Correlation between metamorphic and magmatic processes in Central Badakhshan.

But the most characteristic aspect of all this Hercynian metamorphic sequence is the frequent appearance of horizons, with typical high thermal facies metamorphism. All these horizons, to whatever zone or facies of metamorphism they are joined, have mineralogical associations typical of the hornblende hornfels facies.

This shows that the prevailing element in the Hercynian metamorphism

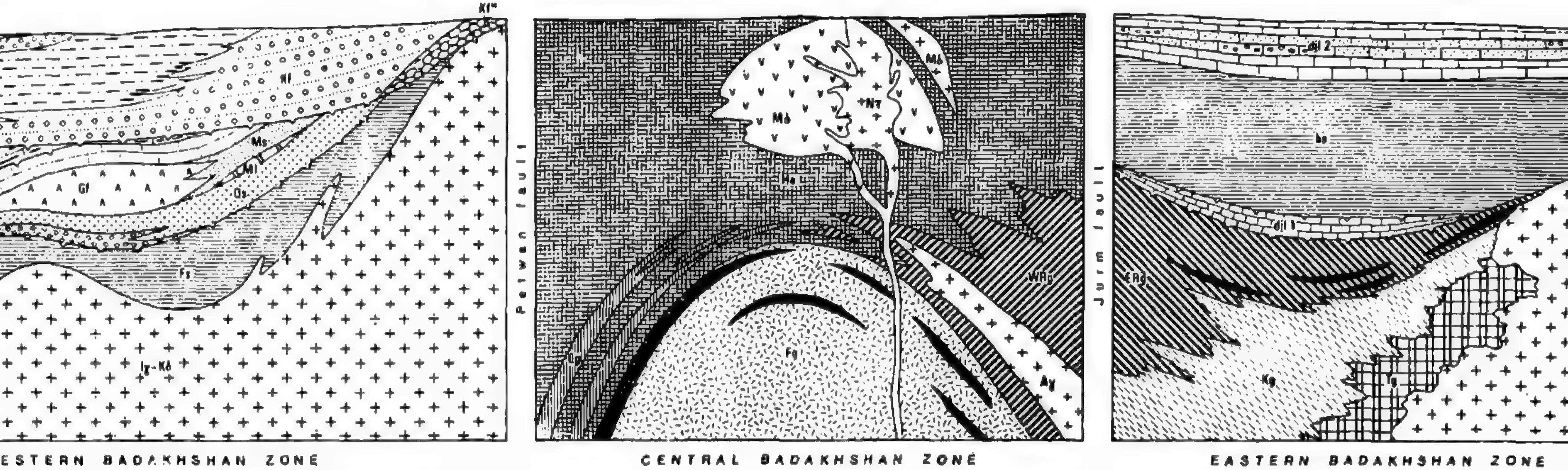

Fig. 30 - Scheme of the stratigraphic correlation in Central Badakhshan and Kataghan.

akhshan Zone - q = Quaternary deposits, Tgr = Taluqan Gravels, Kf = Kokcha Formation: Tah Jari member, K
uch member, Kf'' = Ganda Qol member; Akf = Ambar Koh Formation, Bf = Bluti formation, BDl = Baba Darwes
Gf = Gazestan Formation, Ms = Mohammed Aba Sandstone, Ml = Mashad Limestone, Qs = Qara Bulaq Fo
= Shingan Formation, Fs = Farkhar Formation, Iγ-Kδ = Jalmish Tonalite & Kakan Quartz Diorite.

khshan Zone - Mδ = Muzung Gabbro, Nτ = Naghz Darrah Tonalite, Aγ = Abu Abdal Granodiorite, Ha = Halqa
ite, Qg = Qara Mugul Gneiss, WRg = West Rabat Gneiss, Black = Calphyre and marble, Fg = Faydzabad Gneiss

khshan Zone - djl 2 = Wuran Shar limestone, djl 1 = Kalawch limestone, bs = Blach Shales, ERg = East Rabat G
= Calcphyre and marble; Kg = Kurkhu Gneiss, Tg = Tarang Gneiss, Bγ = Baharak Granodiorite.

of Central Badakhshan was the temperature that accompanied wide fusion, palingenesis and granitization process, though in a rather low range of pressures, always varying in the limits of the almandine-amphibolite zone. The development of migmatite in analogous conditions was described with surprising analogy by FYFE, TURNER & VERHOOGEN (1958), according to whom metamorphic rocks of the almandine-amphibolite facies can exist together with granitic spindles from a temperature of 700°, provided the spindles are supersatured of H_2O.

In this case mineralogical associations of high temperature are found also at great distance from granitic injection and migmatites, so that all the region must have undergone a very high temperature gradient. With such anomalous thermodynamic conditions, the vertical development of the metamorphic facies is incomplete and atypical, mostly if we consider the quite total lack in kyanite and staurolite in the pelitic associations. To the above described phenomena of synkinematic granitization with limited and local mobilization of granitic spindles, a strong late-orogenetic magmatism of Upper Paleozoic—Lower Triassic age is opposed. It develops with batholithic intrusions concordant along the western side of the region, gathered under the name of Jalmish Tonalite and Kakan Quartz Diorite.

Such intrusions align with the axial Hercynian batholith of Northern Pamir and seem to be placed at the margin between the Hercynian orogene and a cratonic zone of late sinking, corresponding to the Upper Amu Darya Depression. The magmatism is originally tonalitic and, during a rather long period of deep differentiations and intrusive reactivations, it pass to leucogabbric, quartz-dioritic, aplogranodioritic and leucogranitic facies.

During the Mesozoic age, the axis of the geosyncline gradually moved eastward as fas as the Faydzabad zone, stiffened by Hercynian magmatic and metamorphic processes, formed a high structural unit, divided by the rising Alpidic geosyncline with a system of fault slopes coinciding with the present Jurm valley going on northwards as far as the Dasht-i-Pan, Kulan, and Koh-i-Sur-Khan zones.

A later magmatic activity with prevailingly basic character, took place into the old Hercynian tectogene in the zone north of Faydzabad during the end of Cretaceous. In Halqa Jar Amphibolite gabbroic magmas with monocline pyroxene and olivine with marked syntectic modifications for assi-

milation of calcareous-dolomitic rocks, described as Muzung Gabbro, were intruded under conditions of tectonic stability.

At the southern margin of the mass, they came up in form of differentiated sialic tonalitic stocks with filonian leucogranitic and pegmatitic manifestations, together with quartz dioritic facies, probably originated by syntexis phenomena. This complex was named Naghz Darrah Tonalite. This Cretaceous magmatism corresponds to the basic plutonic very differentiated manifestations of Central Pamir, mentioned by some Russian authors as related with the Cimmerian late-orogenic activity. Anyway, it probably does not represent the deep correspondent of a basic volcanic activity of oceanic character, both for the lihologic pattern and the structural position.

The subsident basin with miogeosynclinal character placed east of the line of Jurm valley, undergoes the first orogenetic Alpidic deformations probably during Cretaceous already.

The Hercynian metamorphic formations making the base, as Kurkhu Gneiss, are chiefly involved in a cycle of metamorphism and granitization of great intensity and extension.

During Eocene, great masses of anatexitic granite take place between the polymetamorphic granitized gneisses up to agmatitic and the sedimentary formations with lower degree of metamorphism, among which the black slates mainly. The phenomenon, in its upper part, seem to be ascribable to selective anatexis of the metamorphites of the Hercynian cycle, mainly for a zoned disposition of the granitoid masses forming Baharak pluton, with quartz plagioclasites in the basal part and leucogranites in the summit part.

The granitization phenomena overlie a phase of intense mechanical deformation that reached the crystal scale. This agrees with the opinion, expressed in a preceding chapter, that in Central Badakhshan the Alpidic synorogenetic migmatization reaches zones of higher metamorphism than the Hercynian one, overlying effects of embrional epidermal tectonism.

A powerful bending and lifting of the region included between the Hercynian orogene of Faydzabad zone and the cratonic unit of South-west Pamir followed this synorogenic activity.

Along the fracture zone of the Jurm valley, during Miocene, there was the coming up of granitic late orogenetic masses forming Abu Abdal pluton. The magmatic phase was preceded by diffusion of sodic-potassic solu-

tions that gave birth to a thick wrapper of migmatitic gneiss and ended with the penetration of aplitic-pegmatitic spindles into the country rock.

The principal magmatic mass came up in concordant lenticular plutonian form, with massive and homogeneous aplogranodioritic composition. With this activity, dated about 13 M.Y., the great geological evolution of Central Badakhshan ends. It gathered in the space of a few tens of kilometres the products of three orogenetic cycles, at least, in a complex but highly expressive and charming mosaic.

The evolution goes on westwards with the sinking of Upper Amu Darya depression filled with thick Neogene molasses, but in Badakhshan and in Pamir the exceptional frequence of deep seisms shows that the structural, and probably magmatic settling of the region has not yet ended (see page 331).

III. GEOLOGY OF THE LAKE SHIWA AREA

1. INTRODUCTION.

The geological survey of the territory surrounding Lake Shiwa was made by A. DESIO and G. PASQUARÈ during the 1961 expedition. It was limited to an area stretching about 20 km long from east to west, from the village Arakht and the northern branch of the lake to the Nakhshir Par valley. The sequence outcropping along the northern side of the lake and the bottom of the Nakhshir Par valley was surveyed with some details (Fig. 31).

The petrographical study of the specimens was made by P. SPADEA RODA who compiled also the sections dealing with the field observation. She was supplied with the maps and the field-books by the two surveyors and benefited of their geological assistance.

In the present chapter the Pleistocene deposits, which are largerly spread in the Lake Shiva area, are not taken into consideration. They are described later in the chapter dealing with the Pleistocene of Badakhshan. As we have mentioned in the introductory section of this volume, the area of Lake Shiwa was visited by H. SAWATA in 1960, that is one year before our expedition, but his report appears in the same year of our first report (1962).

We have known some year later this report and the same happened to SAWATA about our preliminary report of 1964 (by DESIO, PASQUARÈ & SPADEA).

SAWATA mentions very summarily the geology of the surroundings of Lake Shiwa and only the glacial and fluvio-glacial deposits are described (see page 350). His report contains also a geological sketch map, at the scale 1:278.000, of the northern part of the drainage basin and of the upper Nakhshir Par valley. The following lithotypes are drawn: « hornfels, slate, phyllite, schist; banded gneiss, schistose hornfels; granitic rocks, gneissose granite ». The age of all these lithotypes was unknown.

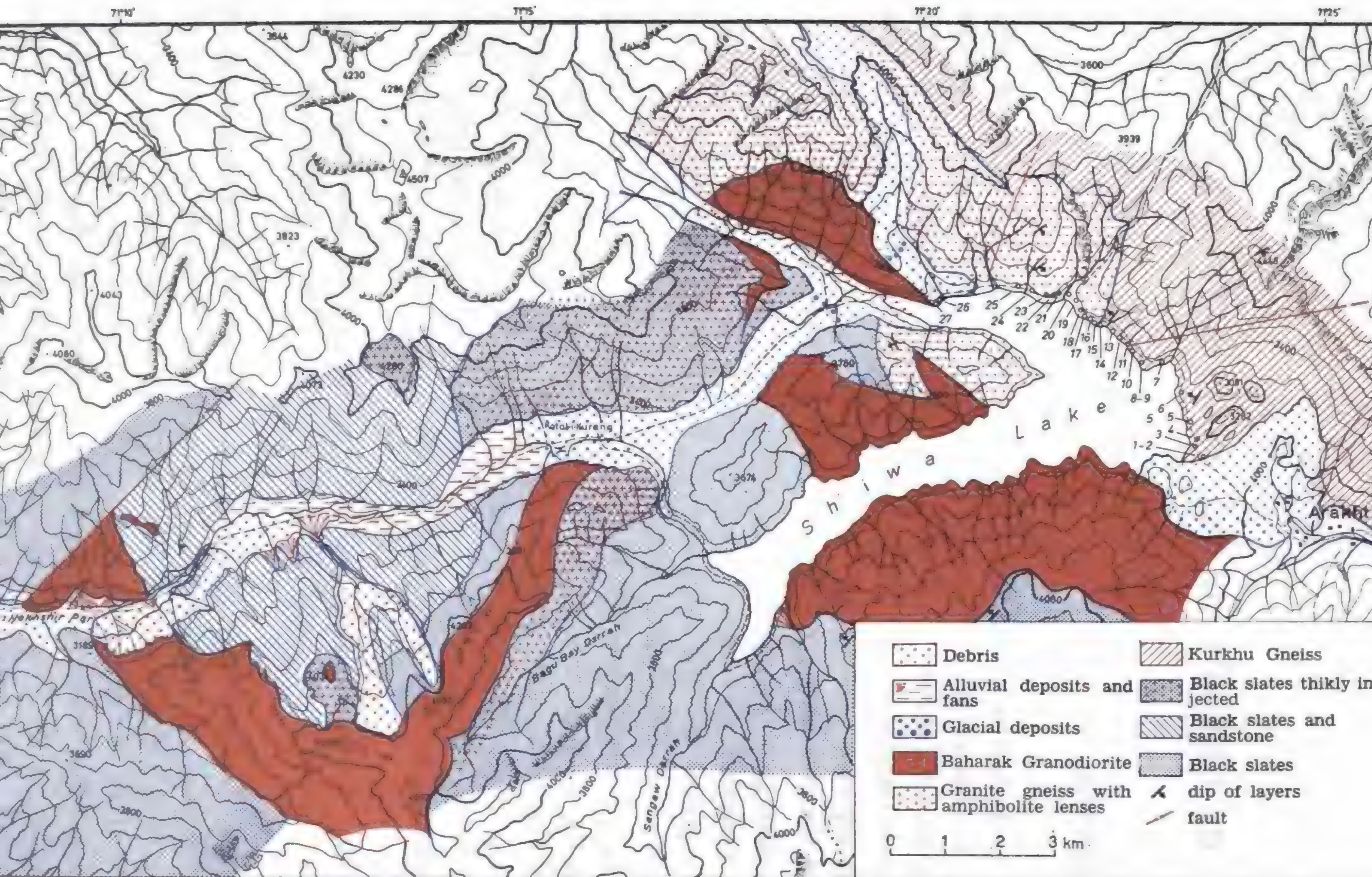

Fig. 31 - Geological sketch-map of the Lake Shiwa area by DESIO & PASQUARÉ (1961).

The most recent geological report was published by V. G. LEONOV in 1969 but it concerns an area situated a little outside from the area under examination (WNW from Lake Shiwa). A geological sketch-map at the scale of about 1:350.000 is annexed to this report.

According to LEONOV the considered area (1) is divided in three zones having the following composition:

A. *Western zone*: 1. banded black limestone, 2. variegated deposits, 3. clayey sandy rocks, 4. silty shales and marls, 5. black layered marls, 6. black massive limestone;
B. *Central zone*: 7. extrusive and quartzose rocks, 8. sandstones;
C. *Eastern zone*: 9. gypsum and dolomites, 10. shales.

The Central zone is crossed by an intrusion of biotite granite and porphyroid granite, and the Eastern zone by a dyke of muscovite granite. No fossils were found by LEONOV, but the author correlated the stratigraphical units with those of Pamir.

The geological similarites with the rocks of Lake Shiwa are very few. Only the dark shales with granite intrusions of the Eastern zone and the sandstone of the Central zone are correlatable. The Western and Central zones represent the northern continuation of our Central Badakhshan tectonic zone (see page 327).

2. GEOLOGICAL AND PETROGRAPHIC FEATURES.

2.1. General Structure.

Four major units were recognized in the area under examination. The deepest unit, which presumably is the most ancient, is a *complex of migmatite* cropping out along the Lake Shiwa coast as far as the eastern survey boundary. The stratigraphy of this complex, which contains a great variety of rocks, characterized by the frequent repetition of the same lithological types, is obscured by the intense metamorphism and granitization. Strong tectonic deformations, on both a small and a large scale, have caused local overturning of the series and repetition in the sequence. The thickness of the complex should amount to a few hundred metres.

The migmatite complex is to be mainly correlated with the Kurkhu

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(1) In the LEONOV's sketch-map the Nakhshir Par river is drawn as an emissary of the Lake Shiwa, but this is not correct. The lake have only a subterranean emissary in the Arakht valley. A watershed divide the drainage basin of the Lake Shiwa from that of Nakhshir Par (see pag. 352).

Gneiss and partially with the East Rabat Gneiss of the area situated between the lower Zardew and the Warduj rivers.

In the central part of the surveyed territory intensely displaced and mylonitized granitoid and pegmatitic rocks prevail. Due to their lithological uniformity and the features characteristic of intense cataclasis and mylonitization, the rocks of the central part have been grouped in an unit distinct from the migmatite complex (*Blastomylonitic and cataclastic granite and granodiorite*).

Westwards on, along the Nakhshir Par valley, massive granite and granodiorite (*Baharak Granodiorite*) appear beneath a paraschists cover (Fig. 32). They have sharp intrusive contacts with the paraschists, while they show gradual textural passage to the blastomylonitic granite and granodiorite.

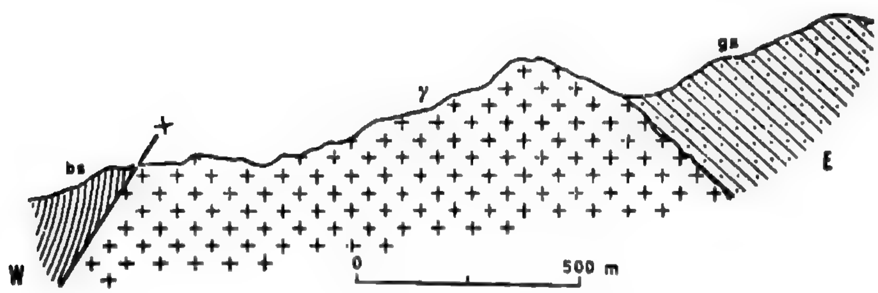

Fig. 32 - Geological section across the contact between the granite (γ) the black slates (bs), and the grey sandstone (gs) on the right hand side of the Darya Nakhshir Par (from Desio's field book).

The paraschists constitute the fourth unit, and are normally represented by graphitic slate and fine-grained weakly metamorphosed graywacke, constituting a thick apparently monotonous sequence stretching for many kilometres to the west and south of the area. These low-grade metamorphic rocks have been provisionally named *Black Slates* (Desio, Martina & Pasquarè, 1964). Near their contact with the granite and granodiorite the Black Slates show complex high-grade metamorphic transformations by which particular mineralogic associations were produced.

The large scale structures recognizable in the surveyed area are a broad anticline with its axis trending NE-SW and crest lying to the east of the area where it lies parallel to a narrow, weakly folded syncline, and an important zone of fracture dislocation, oriented NE-SW, crossing the central part of the area.

The migmatite complex and the blastomylonitic and cataclastic granite and granodiorite belong to the western limb of the anticline. The schistosi-

ty planes vary in strike from ENE to NNE in a westerly direction, while the inclination increases from 25° NNW to 70° WNW. As the fracture zone is approached the inclination becomes steeper until the schistosity is vertical or overturned to the south-east. At the same time the structure of the rocks becomes more and more evidently cataclastic and laminated until the rocks pass into mylonites and blastomylonites. These ones define the movement zone dividing the migmatite complex from the massive granitic rocks.

An other fault brings the Black Slates into contact with the granites and granodiorites outcropping in the western part of the region (Fig. 32). In the other zones contact between the granitic rocks and the Black Slates is not tectonic, but intrusive and characterized by an intensely injected zone. The Black Slates vary in strike from NE—SW to N—S and they usually dip westwards. The direction of dip locally changes to the south and east in the zone of contact with the granites and granodiorites.

2.2. Migmatite Complex.

Field Observations. — Banded gneiss is the dominant rock type in the migmatite complex of the Kurkhu Gneiss (page 178). They show alternating light and dark bands measuring a few decimetres to a few metres across. The bands themselves are parallel or almost parallel to the general gneissosity and are also parallel with one another over considerable distance. A locally developed agmatitic complex, some tens of metres wide, is the exception to this. On the small scale each band often shows a subdivision into narrow bands rich in either colourless or dark minerals. The leucocratic bands vary from a few millimetres to a few centimetres in width, while the mafic bands are one to a few millimetres thick. Augen structures are common, mostly in less heterogeneous banded gneiss. The darker bands, recognizable on the large scale and representing a more or less altered palasome, are composed of amphibolite, garnetiferous amphibolite, and biotite-plagioclase gneiss. Gradations from these rocks to leucocratic banded gneiss and augen gneiss were observed in the field. The olo-leucocratic rocks, occurring as large layers and lenses, have quartz-feldspar compo-

sition, coarse to medium grain size and usually show a gneiss texture. They can be defined gneissose pegmatite, or better, according to MEHNERT's terminology (1968) pegmatoid. The distribution of the structurally different migmatites exposed along the pathway from Arahkt to Kotal-i-Kurang (1) is followingly outlined. The migmatite outcropping furthest to the east of the surveyed area, that is on the saddle between Lake Shiwa and Amu Darya valley, above the village Arakht, is a medium-grained banded gneiss, with biotite and a little garnet, containing small feldspar porphyroblasts. Gneissose pegmatite, which occurs in lenses and conformable bands up to half a metre thick, often containing oriented biotite-rich dark trails, intercalates the migmatitic gneiss.

To the east of Lake Shiwa, more variable and heterogeneous migmatite occur. The banded gneiss gradually becomes finer grained and more femic; the striping disappears until only augen structure is present. Pegmatite is always diffused and often unconformable with the foliation.

With the occurrence of amphibolite as darker rocks, the migmatite is more heterogeneous and at the same time the foliation either disappears or becomes very irregular. Medium-grained amphibolite (metagabbro) constitutes irregular masses surrounded by pegmatitic and perhaps aplitic veins. This agmatitic complex is followed by gneiss composed of light-coloured bands and lenses regularly alternating with dark bands of amphibolite which are more or less transformed by metasomatism (smal sialic lenses and stripes are frequent in these rocks) or, more often, by massive coarse-grained garnetiferous amphibolite. Sometimes garnet is enriched at the borders of amphibolite lenses at the contact with the pegmatite. Augen or finely banded biotite or amphibole migmatitic gneiss alternate with the amphibolite and prevail westwards.

An abrupt change of rock-type occurs near the spur projecting into the middle of northern coast of Lake Shiwa. Here the medium-grained migmatitic gneiss is in contact with coarse-grained granitic or pegmatitic rocks. The rocks richer in mafic components (granitic augen gneiss) have a gneissic augen structure, the pegmatite being slightly foliated or massive. Most of these rocks are cataclastically deformed.

The granitic augen gneiss is characterized by the presence of lenses or

(1) *Kotal* means *pass*.

eyes of potash feldspar composed either of single crystals or of porphyroblasts gathered togheter in groups. Quartz and plagioclase crystals are sometimes united with them, forming bigger lenses. In hand specimens these eyes and lenses have the appearance of pegmatitic concrections (BARTH, 1962).

Relics of mafic minerals forming trails oriented parallel to the general foliation of the adjacent rocks remain in the pegmatite.

Medium fine-grained dark rocks are frequently intercalated within the granitic augen gneiss. The most common types are biotite-plagioclase gneiss which shows moderate variations of the crystals grain size together with variation of the ratio between colourless and dark minerals, being unchanged the composition of the rock-forming minerals. The thickness of the biotite-plagioclase gneiss is about 300 m. Basic amphibole rocks (fine-grained amphibolite, probably derived from plutonic rocks) are much more scarce, and occur as bands from 2 to 4 metres.

PETROGRAPHICAL FEATURES. — a) Amphibolite, biotite-amphibole schist. The amphibolite and garnetiferous amphibolite are coarse to fine-grained, dark green, massive rocks, characterized by a weak schistosity recognizable only under the microscope.

Garnet-poor amphibolite can be identified as meta-gabbro both by textural and mineralogical features. One sample (61 AP-17/4; Plate A, fig. 1) is essentially composed of green hornblende and zoned plagioclase (An_{43-27}) (1). Quartz, as roundish grains included in the plagioclase, clinopyroxene, iron-ore, biotite and garnet are also present together with small quantities of apatite and zircon. Pyroxene ($2V\gamma = 56°$-$57°$; $c:\gamma = 44°$, with moderate dispersion) occurs as relics included in amphibole and largely replaced by it. Ilmenite that is the most abundant accessory, is always surrounded by a reaction rim of small titanite crystals. The structure of these rocks is characterized by an even developement of amphibole and plagioclase and by only a vague orientation of the biotite flakes.

The garnetiferous amphibolite (61 AP-17/5) is darker in colour and coarser-grained than the rocks mentioned above. Its structure is slightly oriented, due to the alignement of garnet granoblasts in trains and the align-

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(1) All plagioclase compositions were determined with the universal stage using the zone method in sections [100] in albite twins. The diagram reported in TRÖGER (1959) was employed.

ement of sialic patches. The distinctive feature of the rock is the abundant content of garnet and its development as big roundish poikiloblastic crystals, that include unoriented scattered grains of all the other minerals of the rock, so suggesting to have grown under static conditions. The other essential components of the rock are hornblende, plagioclase (An_{28-27}), quartz, biotite and iron-ore (mainly ilmenite). Well crystallized apatite and zircon also occur. The basic rocks outcropping in the western part of the area underlain by migmatites are represented by fine-grained biotite amphibole schist (61 AP-17/14). The mafic components of the rock are amphibole, biotite and sphene. The amphibole is a strongly coloured hornblende, with pleochronism, for γ, bottle-green changing to brightly blue-green at the edges and also in smaller grains. It usually appears as well-developed, roughly oriented, poikilitic porphyroblasts. The biotite, brown-green in colour, seldom transformed to chlorite and epidote, lies in undulating streaks which impart a weak foliation to the rock. The S_2-surfaces defined by biotite flakes lie at low angle with the chief schistosity and are marked also by a shattering of plagioclase and hornblende grains and the presence of well developed sphene crystals (Plate A, fig. 2). The chief leucocratic component of the rock is plagioclase (An_{30-28}) which forms lenses made up of gathered granoblasts. Quartz roundish granules are interposed among them occasionally associated with pellucid potash feldspar of late origin. The same feldspar, in addition to quartz, is sometimes found within the plagioclase in the form of replacement blebs developed along the cleavages of the host and as small veins fitting microfractures in the plagioclase. In a preliminary way it can be supposed that the biotite-amphibole schist is the product of a local advanced metamorphism accompanied by biotitization of hornblende in an amphibolite, probably having as starting material a gabbro.

b) Plagioclase-biotite gneiss (East Rabat Gneiss) [1]. A distinct feature of these rocks with respect to some of the less heterogeneous banded gneisses having a comparable mafic content and structure is their extreme paucity of potash feldspar, even in the most leucocratic types. Their mineral assemblage is simple and constant: plagioclase (oligoclase-andesine) quartz and biotite occur as essential components, while

(1) See page 165.

apatite, allanite, zircon and, rarely, potash feldspar are the accessories.

The proportions of biotite and colourless minerals, chiefly of quartz, as well as texture (chiefly grain size) vary considerably in the examined samples (61 AP-17/12, /13, /6). Concurrently with an increase of sialic minerals the texture varies from medium fine-grained to medium-grained with an increasingly porphyroblastic (plagioclase-porphyroblastic) character (Plate A, figs. 3, 4). The structure is clearly gneissose. In the most leucocratic rock (61 AP-17/6) a vague banding, due to alternating bands more or less rich in biotite, is shown. In all the samples reddish-brown biotite and quartz as strained granules with jagged limits compose schistose streaks around large plagioclase crystals. A scarse matrix of small plagioclase and quartz grains is also interposed. The larger plagioclases occur as single crystals, albite and pericline often twinned, lacking of a prevalent optical orientation, sometimes with post-crystalline deformations. They contain very rare biotite and quartz inclusions, and are sometimes corroded by quartz. The plagioclase composition is slightly variable due to zoning (generally reverse) and ranges from 35-33% An in the more mafic rock to 32-30% An in the most leucocratic type. The potash feldspar occurs in very small quantity in the sample 61 AP-17/6 as blebs included in the plagioclase, and as interstitial small patches in the groundmass. At the contact with potash feldspar the biotite flakes are fringed and bleacked. It seems evident that the plagioclase-biotite gneiss was derived from the same rock-type and by the same process in more or less advanced stages. The parent rock should be a paragneiss (metagraywacke). The variations in structure and modal composition in the studied samples and the slight increase in the Ab content of the plagioclase suggest a progressive plagioclase blastesis accompanied probably by Na-metasomatism and silicization, namely a metasomatic process (Misch, 1968).

c) Banded gneiss (Kurkhu Gneiss). It is the predominant rock type in the migmatite complex. From the mineralogical point of view, it is characterized by the presence of biotite as the essential mafic component (with the exception of a rock where the amphibole is prominent), of potash feldspar (orthoclase) and myrmekite. The plagioclase is invariably of oligoclase composition (about 20 to 30% An), but becomes albitic in borders or reaction rims against the potash feldspar. The texture of these

rocks are alwaye gneissose even in the lithologic types richer in colourless components (Plate B, figs. 1, 2).

A fine-grained garnet-bearing migmatitic biotite gneiss (61 AP-17/3) with a banded augen structure, is representative of types poorer in sialic components. Plagioclase (An_{30-20}), orthoclase ($2V\alpha = 38° - 50°$), and quartz are, present in the darker schistose bands, and also form thin discontinuous layers which sometimes widen into small « eyes.», composed of larger plagioclase crystals. The biotite has a strong brownish-red pleochroism and occurs as small frayed flakes, oriented parallel to undulating surfaces. Near the garnet the mica shows a green colour. Garnet is developed as irregularly shaped poikilitic grains. The plagioclase crystals contain roundish quartz inclusions and replacement string perthites of potash feldspar. They show weak deformations and are sometimes crossed by thin veins filled with quartz, myrmekite and biotite. Myrmechite borders are often found around the plagioclase at the contact with potash feldspar. Sometimes, instead of myrmekite there is a thin border of untwinned albite. Allanite is prominent among the additional minerals. Apatite, zircon, iron oxides and sagenitic rutile, segregated from biotite, also occur.

Garnet-free migmatitic gneiss generally less mafic than the rock described above, is the most frequent rock types. Progressive increase in sialic components, mainly potash feldspar, produces a medium-grained migmatitic gneiss with augen banded (61 AP-17/1) or banded (61 AP-17/11) structure. The mineral composition is comparable with that of a granodiorite. In the augen banded gneiss there is as rather uniform distribution of biotite and sialic components, forming narrow undulating, discontinuous streaks and wider bands or lenses, respectively.

The migmatitic banded gneiss is poorer in biotite and shows a sharper division between the biotite-rich and quartzose-feldspathic bands. The mineral association is always plagioclase (An_{27-23}), potash feldspar (sometimes with typical microcline twinning), quartz and biotite. Allanite occurs in addition. The plagioclase crystals are sometimes fractured and cemented by quartz or chlorite, while corrosion by quartz and potassium feldspar is evident; myrmekite always occurs near the latter.

Only one sample of banded amphibole-bearing gneiss (61 AP-17/7) was examined. Macroscopically the rock shows a very regular and fine banding and a rather fine grain size. The sialic layers, with granoblastic texture,

are composed of quartz, plagioclase (An_{27-24}) and orthoclase ($2V\alpha = 40°$). The quartz occurs in ribbon-like flattened lenses parallel to the schistosity, composed of unoriented granoblasts. Also the feldspars have a marked orientation and a lenticular shape. In the dark bands, hornblende and brownish green biotite, occasionally chloritized, occur in equal proportion toghether with small plagioclase and quartz grains. Apatite, zircon, and iron oxides are the accessory minerals; otherwise then in the other migmatitic gneisses allanite is lacking.

d) Augen gneiss (Kurkhu Gneiss). The most sialic rock of the migmatite complex, occurring as bands or big lenses intercalated in the migmatitic banded gneiss, usually with very sharp contacts, is represented by augen gneiss corresponding in mineralogy to granite and granodiorite. The coarse grain-size and the more or less evident porphyroblastic texture of this rock are the principal features that distinguish them from the most leucocratic banded gneiss. The schistosity is defined by biotite streaks and in rare cases also by quartz pseudoschistose bands. The frequence and development of feldspar porphyroblasts and the distribution of sialic and mafic components are rather variable in this group of rocks.

The most homogeneous granitic gneiss (sample 61 AP-17/8) is porphyroblastic due to the presence of large individuals of plagioclase (An_{23-25}) and of perthite-poor orthoclase ($2V\alpha = 56°$). There are also large quartz patches. The matrix is schistose due to oriented biotite laminae and small strained quartz granules; it is essentially composed of oligoclase, myrmekite, quartz and potash feldspar, the latter generally perthite-free and interstitial with respect to the other components. The largest plagioclase crystals are frequently replaced, at different stages of development, by potash feldspar and quartz, and show fractures filled with quartz, albite, potash feldspar and biotite. The largest potash feldspar individuals often include plagioclase as relict myrmekite-rich corroded crystals or as small grains showing a reaction border composed of albite. Albite itself occasionally occurs as thin strips in contact with potash feldspar. Another rock (sample 61 AP-17/9) similar in mineralogy to the above described rock, but with a very heterogeneous distribution of sialic and mafic components, shows an interesting example of metamorphic differentiation and some analogies with the pegmatite gneiss. In hand-specimen (Plate B, fig. 3) feldspar « eyes » and lenses of variable size up to some centimetres

in size are apparent. The matrix is scistose and rich in biotite. The larger feldspar lenses are composed of one or a few potash feldspar crystals containing inclusions, mostly of quartz, and generally bordered by mirmekite. They could be interpreted, like pegmatitic concretions formed in the gneiss by a metamorphic differentiation process (ESKOLA, 1932; BARTH, 1962). The potash feldspar crystals (Plate B, fig. 4) show fractures along which patches with a faint cross-hatched twinning occur. The optic axial angle is strongly variable in different parts of each crystal, from 60° to 80° about, and attains the maximum value in correspondance to the twinned zones with cross-hatched pattern. The feldspar can be interpreted as orthoclase going to transform into microcline. The feldspars composing the smaller « eyes » are either orthoclase ($2V\alpha = 53°$-$54°$) or oligoclase (An_{25}). The matrix is composed of quartz, plagioclase, interstitial potash feldspar and biotite, and is characterized by largely variable proportion of biotite and sialic minerals closely connected to changes in abundance and size of porphyroblasts. Myrmekite is frequent. Among the minor component there are apatite and allanite, as well developed, randomly scattered, crystals.

e) Pegmatite. The pegmatite occurring as major concordant bands and lenses (samples 61 AP-17/1a;-12/10). is coarse-grained, gneissose in texture and contains potash feldspar, plagioclase quartz and micas. The potash feldspar, represented by perthite-poor orthoclase ($2V\alpha = 53°$), is prominent. Quartz and sericitized plagioclase occur in subordinate amount. The latter is largerly corroded by the potash feldspar till to be set in it as relics, biotite is concentrated in small bands surrounded by a granoblastic aggregate of quartz and plagioclase showing considerable myrmekites. Similar quartz plagioclase aggregates are found among the larger microperthite individuals.

A gneissose pegmatite (sample 61 AP-17/2) contains a few unoriented muscovite laminae, included in the potash feldspar. Some ill-shaped flakes show an evident derivation from plagioclase.

RELATED FORMATIONS. — There is some uncertainty in stating a correspondance between the migmatite complex in the Lake Shiwa area and the similar metamorphich formations recognized by DESIO, MARTINA AND PASQUARÈ (1964) in other sites of Central Badakhshan; for this reason no formal name was employed to define the unit under study. In its geolo-

gical position, though complicated by the occurrence of an intensively tectonized belt separating it from the Baharak intrusives, the migmatite complex seems to correspond to the Kurkhu Gneiss and Tarang Gneiss which form respectively the outer and discontinuously the inner country rocks along the eastern southern side of the great Baharak pluton. Petrographically there are many similarities between the rocks of the migmatite complex and the banded and augen migmatitic gneisses from the lower part of the Kurkhu Gneiss and the more heterogeneous migmatites belonging to the Tarang Gneiss, the dark band composed of various amphibolic rocks are also common to all these units. A noteworthy difference with respect to the Kurkhu Gneiss consists in the total absence of sillimanite within the metasome: if sillimanite should be ubiquitous in the Kurkhu unit, it should imply either a lower metamorphic degree, or a primary compositional feature of the original metasedimentary rocks undergone migmatization, that is a lower Al content.

The plagioclase biotite gneiss of the same complex can be attributed to the northern edges of the East Rabat Gneiss outcropping in the Upper Kurkhu valley.

2.3. Blastomylonitic and Cataclastic Granite and Granodiorite.

Field Observations. — An extensive granitic sequence, containing intercalations of basic rocks and paraschists, and characterized by a strong dynamic metamorphism of the rocks, is interposed between the migmatite complex and the granite and the granodiorite. This belt, hundreds of metres thick, stretches from the middle of the northern coast of Lake Shiwa to the mouth of the Ab Ziyan valley. The rocks in this complex do not differ considerably, apart from their intense deformations, from the granitic augen gneiss present among the migmatite. Some basic rocks are also similar to the amphibolite intercalated in the same complex. The sequence, however, differs from the migmatite complex in its rather monotonous and uniform composition. Passage to the migmatite is defined by variations in the structure of the rocks. Passage to the massive granite and granodiorite is gradual by way of a rather wide zone in which the schistosity and

cataclasis decrease in intensity and eventually disappear. The inclination of the schistosity planes at first very steep or even vertical, concomitantly decreases.

Near the contact with the migmatite, the prevailing lithologic types are coarse-grained cataclastic chlorite-bearing granite and pegmatite and biotite augen gneiss containing feldspars up to a centimetre in size. Well laminated amphibolite and mafic biotite gneiss still alternate the granitic gneiss as in the migmatite complex. Further on, basic rocks frequently alternate with sialic rocks, the latter occurring in variously oriented veins and in apophyses. The only heterogeneous migmatite of this unit are so produced. Two other basic bands, about ten metres in thickness, are intercalated in the blastomylonitic gneiss. They are all meta-igneous.

The granitoid augen gneiss, which is the most common rock type and is rather uniform in mineralogy, is coarse-grained and have a cataclastic to blastomylonitic texture. It contains porphyroclastic feldspars up to some centimetres in size and mainly lenticular shaped. More leucocratic rocks represented by cataclastic to blastomylonitic pegmatite and aplite, are associated.

Farther westward along the coast of Lake Shiwa the deformation is at its most intense stage: the schistosity planes vary from vertical to overturned. West of this highly deformed band granite and granodiorite, characterised by progressively weaker deformation special rock types sequence.

Highly metamorphic paraschists, containing sillimanite and garnet, are locally intercalated in the granitic rocks with tectonic contacts, as bands not more than one metre in width.

Petrographical Features. a) Augen gneiss, cataclastic and blastomylonitic pegmatite and aplite. Augen gneiss is distinguished by the presence of porphyroclasts, or phenoblasts, of plagioclase and potash feldspar in a fine-grained, usually schistose groundmass composed of quartz, biotite and/or chlorite and by minor proportions of plagioclase and potash feldspar. Iron oxides, apatite, zircon, allanite and sphene are invariably present in addition. The most developed feldspar individuals are from a few millimetres to a few centimetres in size. In hand specimen they are white, or rose coloured. The latter colour is typical of potash feldspar in rocks of pegmatitic appearance. The matrix, present in

variable proportions in relation to the intensity of the deformations and of the recrystallization, is whitish-grey or whitish-green in colour in the most sialic rocks, and dark-grey in those richest in biotite and in most strongly laminated. The presence of biotite is characteristic of those rocks in which intense crystalline blastesis affected not only the minerals of the ground-mass, but also partially recrystallized the larger feldspar individuals. The presence of potash feldspar occupying the finely granular grounds mass, and the often considerable amount of myrmekite indicate either post-tectonic crystallization or late introduction of alkali material. Despite the intense recrystallisation the effects of deformation are recognizable at every stage, but the imprints of both processes alternatively prevail, as is shown by fabric and by some mineralogical features of the rocks. A highly deformed blastomylonitic biotite gneiss (61 AP-17/20) contains porphyroclasts of plagioclase, showing a normal slight zoning (An_{37-30}) and smaller phenoblasts of perthitic microcline wrapped around by pseudoschistose quartz layers and biotite streaks (Plate C, fig. 1). A fine-granulated matrix composed of plagioclase, quartz and microcline and some myrmekite is interposed between the schistose layers. The most developed plagioclase porphyroclasts are often broken down into fragments, each showing a slight rotation of the twin planes with respect to the adjacent, which are cemented by quartz and non-perthitic microcline. The larger microcline individuals contain a variable amount of thread perthites and have generally irregular or lenticular shape: they are slightly deformed, very limpid and lacking in inclusions of other minerals of the rock. The presence of sphene, often well crystallized, occurring within the biotite streaks or as scattered grains in the granular matrix is another peculiar feature of these strongly deformed rocks.

In less deformed biotite-bearing blastomylonitic gneisses (61 AP-17/16) the plagioclase porphyroclasts are unzoned (An_{30}) and include sometimes microcline as rod or patch perthites, while the larger potash feldspar crystals, up to 0,5 cm in size, have a rather regular shape and are very poor or lacking in perthites. They are usually surrounded by a quartz-feldspar aggregate, very rich in myrmekite. In the peripheral parts of the crystals the potash feldspar penetrates into this aggregate and appears divided into close grains, slightly differing in their optical orientation (Plate C, figs. 3, 4). There is thus a stage of recrystallization with growth of feldspar individuals from smaller

granules. In the matrix the quartz is partially recrystallized, and microcline and myrmekite are rather abundant. Sphene does not occur, while ilmenite is found in association with biotite.

An other blastomylonitic augen gneiss (61 AP-17/15,/22 and /24) of more sialic type essentially differs from the rocks described above in containing potash feldspar almost as abundant as plagioclase, and fewer mafic minerals, represented by chlorite derived together with sphene, iron oxides and white mica, from original biotite of which relics are still recognizable. Owing to the scarsity of chlorite, which does not wrap the large feldspars, but is mostly scattered in small patches or set along fractures, these rocks are less schistose than the mafic types. The effects of the strong deformations are indicated both by the granulation and the stretching of quartz and by the frequent fractures in the large feldspars. In one sample (61 AP-17/24) the mylonitization of the rock was followed by a distinct cataclastic process, which produced fractures cross-cutting both the large feldspars and the matrix. The fractures are filled with quartz, chlorite, and potash feldspar, giving way to sharply defined and often intersecting veins. Potash feldspar occurring in veins is clearly distinct from the feldspar which it crosses, both, in its lack of perthites and in its different optical orientation, or in its granular texture. Perhaps concomitantly with the cataclasis and the deposition of minerals in fracture there was also an extensive alteration of plagioclase into sericite. The latter mineral occurs as flakes oriented parallel either to the (010) and (001) planes in the host mineral, either to the schistosity planes.

Rocks of an even more sialic type, showing various stages of deformation like the granitic augen gneiss, with which they are intercalated, are recognizable both by their mineralogy and by relict texture as being derived from true pegmatite and aplite, the latter garnet or muscovite-garnet-bearing.

A blastomylonitic pegmatite (61 AP-17/19) essentially differs from the pegmatite intercalated in the migmatitic complex and from the more sialic augen gneiss in its finer grain-size and the absence of dark mica. The only coloured minerals are garnet, and tourmaline. Among the feldspars plagioclase of albite-oligoclase composition (about 10% An) is predominant. The potash feldspar is represented by perthitic microcline. The plagioclase is largely corroded by the potash feldspar, and borders of albite or of myrmekite are present at contact between the two feldspars. Quartz occurs as

flat lenticles or ribbons composed of strained grains. Both the plagioclase and, at lesser extent, the potash feldspar individuals are fractured and cemented by quartz, albite and white mica (Plate C, fig. 2). The tourmaline, originally in large roundish blue-green crystals, is often dismembered in splinters recemented by quartz. Garnet too is fractured and often shows retrograde transformation being replaced along the fractures by chlorite and white mica as fine-shaped aggregates.

The blastomylonitic muscovite aplite (61 AP-17/25) is essentially composed of oligoclase (An_{28}), perthite-poor potash feldspar (orthoclase with $2V\alpha = 52°$ partly transformed to twinned microcline) muscovite and quartz; there is also a small amount of garnet and chloritized biotite. The texture of the rock is strongly foliated due to the parallel arrangement of the muscovite flakes and the frequent occurrence of quartz in parallel streaks composed of crushed and strained grains. The muscovite laminae are bent and the feldspars are fractured as a result of deformation. Moreover reactions between minerals and diafthoritic transformations frequently occur. The plagioclase is corroded by potash feldspar, feathery muscovite is developed at the border of the large muscovite laminae by reaction with the potash feldspar, and garnet is partly chloritized. Late albite occurs as thin veins.

Analogous mineral transformations and reactions are also seen in the blastomylonitic garnet-biotite aplite (61 AP-17/27). The rock is essentially composed of microperthitic microcline, oligoclase, quartz, and, in smaller quantitaty, of garnet and biotite. The structure is partly metamorphic, but some features of an aplitic structure are still preserved. The biotite flakes show a parallel arrangement and form thin and discontinuous parallel streaks; small garnet grains, probably derived after crushing of larger crystals, are similary alligned.

b) Metagabbro, garnet-sillimanite schist. The basic rocks outcrropping in the farther eastern part of the mylonitic belt, show some analogies with some amphibolites intercalated in the migmatite complex. They are, medium fine-grained, poorly schistose and slightly cataclastic. The essential mineral assemblage is calcic plagioclase, often zoned (An_{67-40}), green hornblende and biotite; additional components are quartz, iron oxides, sphene, apatite, and chlorite. The plagioclase is mostly subhedral, with elongated habit, and occurs as randomly oriented laths. The amphibole is present as prismatic subhedral to anhedral individuals.

The association between the feldspar and the amphibole gives way to a structure similar to that of a microgabbro or diabase. The calcic composition of the plagioclase and its marked zoning are also indicative of an igneous origin. As a consequence of metamorphism plagioclase locally recrystallized as granoblasts of andesine composition, and some biotite was formed at the expence of the amphibole.

The coarse-grained metagabbro (61 AP-17/23, /23 a) is massive, and strongly spotted by coloured and colourless components in hand specimen. The mineral association is plagioclase (An_{52-30}) and hornblende; quartz, biotite an sphene occur in small amount. The texture of the rock is variable from point to point: plagioclase and amphibole mostly occur as large anhedral crystals, but locally fine-grained patches composed of plagioclase granoblasts, with sutured boundaries, and small biotite flakes are developed. Cataclastic effects are evident: the fractures are partially obliterated by recrystallization or filled with biotite and sphene. The plagioclases are always turbid and twinned according to the albite law. The larger individuals show often a normal zoning and the pericline twinning. They are moderately deformed and partially recrystallized along fracture. Hornblende, strongly coloured (α = pale yellow-brown, β = brown-green; γ = grass-green) and with schiller structure, include scattered biotite flakes and sphene grains. At contact with quartz-chlorite patches (probably original amygdales) the hornblende is fringed by acicular actinolite. Occasionally thulite occurs included in hornblende and surrounded by a brown pleochroic halo.

The paraschist (only one sample, 61 AP-17/21, intercalated within blastomylonitic gneiss could be examined) is similar to the Black Slates at the contact with the Baharak Granodiorite). The rock is fine-grained, dark grey in colour, and is essentially composed of quartz, biotite, muscovite, sillimanite and a little garnet. It also contains small quantities of tourmaline, zircon, iron oxides and apatite. The texture is slightly schistose and evidence of cataclasis is given by deformation of all the minerals, particularly the quartz, which occurs as small sutured granoblasts with strong undulatory extinction. Also the garnet granoblasts are fractured. Sillimanite is chiefly represented by the fibrolite variety, occurring in closely packed bundles of fine needles roughly parallel, and often enclosed in quartz and biotite. Less frequently the sillimanite occurs as larger and more distinct crystals probably

formed by recrystallisation of fibrolite. Notwithstanding the occurrence of high-temperature metamorphic minerals, the structure of the rock is characterized by a still preserved bedding and a relatively fine-grain size. These features suggest that the preferred orientation of minerals in the rock is due to mimetic crystallisation (Spry, 1969) caused by a purely thermal action. The rock can therefore be interpreted as a high-grade pelitic contact schist.

Related Formations. The blastomylonitic granite and granodiorite seem to represent the highly tectonized equivalent of the Tarang Gneiss occurring to the south-west of the Lake Shiwa area at contact with the Baharak intrusion. Notwithstanding the strong dynamic metamorphism, the rocks of this unit can be attributed to an original intrusive or meta-intrusive acid complex like the Tarang Gneiss of the adjacent area. The superposed changes due to the dynamic metamorphism did not completely obliterate the primary features of the rocks chiefly as a consequence of the concurrent large, also if not complete, recrystallization and of the variable intensity of deformation.

2.4. Baharak Granodiorite.

Field Observations. Granodiorite and granite occur as masses with rather limited outcrop in the surveyed area, representing the northern extension of the vast area of plutonic rocks to the south and south-west of the region along the Zardew and Warduj valleys as far as Baharak.

In the southern part of the surveyed area the plutonic rocks outcrop continuously so that they can be ascribed to an unique body. In the northern part they occur as stocks and sills. The outcrop of these rocks can be followed for about 10 km in their longest direction. The contact of granite and granodiorite with the blastomylonitic and cataclastic augen gneiss was surveyed in detail, and the most significant rock types were sampled. Sampling was less frequent in the intrusive bodies and at the contact with the surrounding schists. Insufficient data, therefore, are available to indicate the distributional relationships between granodiorite and granite. Observation made in the field and the available information on the location of

samples indicate that granite forms the lesser extensive and clearly injected masses.

Granodiorite occurs west of the blastomylonitic augen gneiss, into which it grades by progressive decrease in cataclasis and disappearance of schistosity.

Along the sides and bottom of the Nakhshir Par valley, the granodiorite is in contact with paraschists (Black Slates). These schist form the roof of the plutonic bodies over a limited area, and are strongly metamorphosed at the nearest contact with the intrusive rock, being represented by garnet and staurolite-bearing biotite parascists and two-mica schists, locally containing nodules and ligth coloured lenses, that will be described later. In spite of their high-grade metamorphism, these rocks are rather fine-grained, so that they can be compared to the low-grade schists outcropping farther away from the intrusive bodies.

A more or less intensely injected zone, up to 200-300 m thick, was observed between the intrusive rocks and the surrounding schists. The injection zone is quite always present on both sides of the Nakhshir Par valley and as far as the Kurang pass. Unfortunately no sample was collected from this zone. In the farther western part of the region, the contact with paraschists is very sharp, locally due to faulting. Here the most intensely metamorphosed Black Slates were found.

Petrographical Features. Granodiorite and granite are coarse to medium-grained with a slightly porphyric structure, due to the presence of larger feldspar crystals. Their texture is massive and only a moderate cataclasis is recognizable. Most of them are strongly weathered.

The most mafic rock type is a biotite granodiorite containing some amphibole (62 AP-16). Amphibole, represented by a green hornblende, is largely transformed to biotite in which it is often included as relic. The sialic minerals are represented by plagioclase, the original composition of which it is impossible to determine due to complete saussuritization, by quartz, and by scarce potash feldspar. The plagioclase is subidiomorphic and corroded at rims by the potash feldspar. The quartz shows a granoblastic structure. The potash feldspar occurs either as small interstitial patches between plagioclase crystals, or, in a greater amount, as veins filling fractures in plagioclase, or as narrow films surrounding and cementing small

splintery quartz grains. Some veins within plagioclase appear to have been enlarged by replacement. In whatever occurrence the potash feldspar is untwinned and perthite-free. As accessory minerals apatite, zircon and sphene occur.

Dark nodules (schlieren) measuring a few centimetres, are present in the rock. They are composed of hornblende-biotite microgabbro containing some well-developed plagioclase crystals with poikilitic structure due to inclusions of biotite and amphibole, and often transformed to epidote in their centres. The composition of these larger plagioclases ranges from 38% to 30% An. The mafic minerals are closely associated: biotite is mostly formed by transformation of hornblende, in this case an intensely brown-green coloured term. The biotite laminae are often twisted and are bordered by titanium and iron oxides and granular sphene. Many thin late veins of potash feldspar, iron oxides, sphene and chlorite are present in the rock.

In another granodiorite sample (61 AP-15) less weathered than that described above a larger content of potash feldspar is present, while amphibole (a green hornblende) is very scarce. Plagioclase is andesine ($An_{37\text{-}30}$) up to albite-oligoclase ($An_{18\text{-}10}$); along narrow borders in contact with potash feldspar it includes sometimes small ovoidal patches of microcline showing a well-developed cross-hatched twinning. Potash feldspar occurs as interstitial patches of various size, including all the other minerals and replacing plagioclase. Biotite, slightly chloritized and reddish-yellow in colour due to alteration, is partially replaced by albite, microcline and epidote (clinozoisite in radial fan-shaped aggregates) together with finely granular sphene; the feldspars and the epidote occur as lenticular patches along the cleavage planes of the host. In this rock also there are frequent late veins of quartz, albite, biotite and potash feldspar which are intersected by younger veins composed of clinozoisite.

Granite, of which a sample was taken near the most westerly contact between the intrusive rocks and the paraschists along the Nakhshir Par valley (61 AP-11), is a monzo-granite type (STRECKEISEN, 1967). Among the essential mineral components are quartz, extensively sericitized plagioclase and microperthitic microcline, which is slightly more scarce than plagioclase and occurs in individuals with a porphyric appearance showing Karlsbad twinning and including the other minerals at their margins. Plagioclase is sometimes replaced by quartz. Conspicuous myrmekites occur in small

plagioclase crystals surrounding potash feldspar. The coloured mineral of the rock is chlorite, associated with white mica and sagenitic rutile, evidently derived from biotite by alteration. Among the accessory minerals allanite occurs in well developed crystals, slightly zoned and included in plagioclase. Feldspathic veins and chlorite and sericite veins are frequent, as in granodiorite.

The final rock of this group is of granitoid type (61 AP-17/26), similar in composition and texture to the adjacent massive granodiorite, but possessing some features of a metamorphic rock, both in the textural relationships of the individual minerals and in the presence of a slightly oriented structure. Potash feldspar (microcline microperthite) occurs as large rounded crystals (augen) while plagioclase exhibit rather irregular shape. Plagioclase is albite-oligoclase, with slightly variable composition due to zoning. The essential mafic mineral is brown biotite. Albite and sphene are additional minerals, both of late generation; apatite, zircon and tourmaline are also present. Iron oxides otherwise than in granodiorite are lacking. The feldspars show evidence of cataclasis and are concomitantly recemented by various minearls (quartz, non perthitic potash feldspar, albite and biotite), probably introduced at different stages. Quartz on the other hand is undeformed. Plagioclase is often replaced by potash feldspar either at rims or within the crystals. Myrmekite occurs at the contact of plagioclase with potash feldspar. The fractures in plagioclase are partly obliterated by recrystallization of a more sodic feldspar (An_5), partly are filled with a fine-grained aggregate of quartz, biotite and alkali feldspar. The relative amount of the above named minerals varies within different intersecting veins. Crystalline blastesis in potash feldspar gives rise to discontinuous intersecting veins of various size, the larger ones being composed both of quartz with mosaic structure, or of non perthitic potash feldspar, quartz and myrmekite, the smaller ones being composed of very fine-grained quartz and albite. It is noticeable that the veins are only developed within the feldspars, and that they do not occur within the interstitial patches of quartz. This quartz possesses a mosaic texture so that it can be ascribed to postkynematic recrystallization. Biotite occurs mainly as flakes of various size with crystalloblastic appearance, asssociated in nests and small lenses, which sometimes sorround the feldspar, but which more often are included in quartz patches. Sphene occurs

in granules bordering the biotite and formed at the expense of the mica; it composes also small irregular veins.

2.5 Black Slates [1].

Petrographical Features. Normal Black Slates are rather uniform in composition and degree of metamorphism. The most common rock types are pelitic black slates often containing dust graphite, and semischists, grey to black in colour according to the grain size and the graphite content, and generally possessing a distinct slaty cleavage, except those coarser-grained derivatives of sandstones. The mineral assemblage of these rocks is quartz, sericite and chlorite, with variable ratio between quartz and the other components. The arenaceous rocks also contain plagioclase. Additional minerals include zircon, apatite, ilmenite, rutile and tourmaline. The derivation of Black Slates from fine-grained graywacke and from siltstones and clayey silstones is easily recognizable.

Black Slates of higher metamorphic grade, found in the zone of contact with the plutonic rocks, shows a greater variety in their mineral assemblage. These rocks are completely recrystallized, and contain a few new minerals, though in small amount. The rocks are usually fine-grained and with markedly schistose texture.

Rocks with the simplest mineralogy are a muscovite-biotite schist (61 AP-13a) and a staurolite-bearing garnetiferous quartz-biotite-muscovite schist (61 AP-13). The first sample is characterized by irregular light and dark bands, some millimetres in width, where biotite, represented by a red coloured variety, and muscovite alternatively prevail. The mica laminae mostly show a decussate texture and only a vague preferred orientation. Very scarce components of the rock are quartz, plagioclase, tourmaline and iron ore. Plagioclase, of oligoclase composition, occurs in small turbid granoblasts. The second sample is characterized by a rather fine-grain size of

(1) Different types of black slates were described in other sections of this work, like the Farkar Slate, the Furmoragh Slate atc. The most similar type to the slates of Lake Shiwa area seems to be represented by the Feurmoragh slates, but no particular investigation on this questions was made during the geological survey; therefore we prefer to describe separately the black slates of this area.

both quartz granules and reddish biotite and muscovite flakes and by plentiful of dust opaque grains which impart a turbid appearance to the groundmass. Staurolite is present in small amount as isolated poikloblasts about 1 mm in size, often twinned and which show a preferred orientation parallel to the schistosity. The garnet occurs as small porphyroblasts, 0,5-1 mm in size, containing roundish quartz inclusions.

The most interesting rocks in the group under study were found about 3 km downstream from Kurang pass in the nearest contact with granodiorite. They are garnetiferous quartz-biotite-graphite contact schists, containing moderate amounts of fibrolite, muscovite and staurolite (61 AP-12) and garnetiferous biotite-muscovite-quartz-graphite contact schists with (61 AP-12a,-14a,-14b) or without (61 AP-14c) staurolite in their groundmass. The first named rock types essentially differ from the latter in their greater proportion of quartz with respect to micas. All these rocks contain light nodules with square or cruciform sections (61 AP-12a, -13a, -14b, -14c) or rod-shaped volumes (61 AP-12) composed of kyanite, muscovite, staurolite, andalusite, fibrolite and sillimanite ([1]) and, in samples 61 AP-12, -12a, of quartz and cordierite. The latter mineral is very scarce and totally absent in the ground-mass. Staurolite and the three aluminum silicate polymorphs may all coexist in the same volume; sometimes, however, sillimanite and/or andalusite may be lacking. The ground-mass of these rocks is fine-grained with planar or undulating scistosity: in both cases the schistosity is marked by the arrangement of the mica flakes, mainly muscovite, and by the disposition of the opaque grains. Folding results to be sincrystalline as to the muscovite and pre- to sincrystalline as to the biotite. The dark mica, in fact, occurs either as small flakes associated with muscovite with parallel arrangement, either as more developed flakes which lie oblique or transverse to the schistosity. The difference between the two types of biotite is not marked because it is possible to find lamine of intermediate size and orientation. The garnet generally occurs as porphyroblasts, about 1-3 mm in size, with turbid cores due to opaque dusty inclusions, and massive inclusion-free borders, probably resulting from overgrowth. Apatite, zircon

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(1) The terms sillimanite and fibrolite are referred to the sillimanite occurring as squat prims and as mats of fine needles, respectively, which are generally retained to represent two distinct phases (CHINNER, 1961; HOLLISTER, 1969), possibly differing in their composition and/or crystal structure (ZEN, 1969).

and ilmenite are constantly present as accessories while tourmaline (a brown-green variety) occurs in only one sample (61 AP-12).

The above mentioned rod-shaped volumes are moderately developed both perpendicular to and within the schistosity surfaces. In the samples with planar schistosity they protrude in the schistosity planes, as randomly oriented rods a few centimetres long. They are oval or spindle-shaped in section. In other samples, which are richer in biotite and generally folded, the nodules 0,5 cm to 2 cm in size, have regular geometrical outlines: they are either square or greek-cross shaped (Plate D, figs. 1, 2, 3). In this case the schistosity is sharply crossed-out by the nodules, perpendicular to the lineation. At the opposite edges the schistosity has a trend conformable to the nodules. A folded sample (61 AP-14c) contains nodules, with approximately square section which are slightly rotated in consequence of folding; in this respect there is an asymmetry to the schistosity surfaces in sections perpendicular to the lineation (Plate E, fig. 1). Near the border outside of one nodule composed of muscovite and of minor amounts of kyanite and staurolite, andalusite occurs as porphyroblasts pale pink in colour poikilitically including the minerals of the groundmass, particularly opaque grains and mica flakes (Plate E, fig. 2). The inclusions show a parallel rectilinear arrangement. It is clear, therefore, either that andalusite is pre-tectonic as to folding, either that it grew under static conditions and that it belongs to a later distinct generation with respect to the andalusite from which, as will be said later on, the nodules were derived.

Notwithstanding the variable shape a common origin of the lenses and nodules under study from andalusite, probably the chiastolite variety, is supposed. This interpretation seems to be the only reasonable, and is also suggested by a number of similar occurrences in various areas (Tilley, 1935; Dike, 1951; Hietanen, 1956; Pitcher & Read, 1963; Woodland, 1963; Workman & Cowperthwaite, 1963; Shams, 1965; Hollister, 1969). Preexistence of andalusite in the rod-shaped volumes seems to be more doubtfull than in the squat prismatic ones because the rods show ill-defined outlines in section, passing laterally into narrow finely granular bands, mostly composed of fibrolite, sillimanite and staurolite, or of biotite and fibrolite, the latter finely crimped. In this case it can be supposed that either andalusite formerly grew into knots which can represent an intermediate stage of development of a porphyroblast, or that during replacement the andalusite

porphyroblasts lost their individuality. An alternative hypotesis could be that these nodules were derived from original clayey concretions and/or by a process of metamorphic differentiation.

While the rod-shaped volumes are rather uniform in their mineral assemblage, the square- and cruciform-outlined volumes show quite variable proportions of the composing minerals, even in the same area. In the first case (61 AP-12) the following minerals occur, in decreasing proportions, that are: muscovite, kyanite, staurolite, quartz, plagioclase, andalusite, sillimanite and fibrolite. A decussate texture is shown by muscovite. The coexistence of the three aluminum silicate polymorphs, with fibrolite in addition, is highly characteristic and a variety of textural relationships among them and with staurolite is observed (Plate F, figs. 3, 4). Kyanite occurs either in fan-shaped aggregates or as single elongated crystals surrounded by muscovite. Rarely kyanite occurs in epitaxial relations both to staurolite and to andalusite, with the (100) crystallographic plane of kyanite parallel to the (010) plane of staurolite, and the (100) crystallographic plane of kyanite parallel to the (100) plane of andalusite, respectively. Andalusite is colourless and occurs as discrete unoriented crystals either irregularly shaped and poikiloblastic, or idioblastic and free of inclusions, the latter generally being in epitaxial relation to kyanite. Borders composed of vermicular symplectite of andalusite or sillimanite and quartz are occasionally found. Fibrolite and sillimanite are generally present toghether near the borders of the nodules, sillimanite occurring near or within mats of fine needles of fibrolite as limpid, parallel oriented prisms of small and rather variable size. While fibrolite is also a component of the groundmass, where it occurs as discrete mats or composes more extensive crimped strips, sillimanite is only present within the nodules. Staurolite is often closely joined the two aluminum silicates as small very irregular grains, so that hardly resolvable aggregates can result. The textural relationships suggest a possible origin of both sillimanite and staurolite from fibrolite. The most frequent occurrence of staurolite, apart the one recorded above, is as euhedral, randomly oriented prisms often twinned and with sponge-like cores due to light vermicular inclusions. It is doubtful wether the staurolite present within the rod-shaped volumes represent a distinct occurrence with respect to the staurolite present in the groundmass of the rock: this one is subhedral, untwinned and roughly oriented parallel to the foliation, and always

contains rather coarse-grained drop-like inclusions of quartz, but it does not differ in size from the first type.

The square- and cruciform-outlined volumes derived from andalusite porphyroblasts in the garnet- and staurolite-bearing quartz-biotite-muscovite-graphite contact schist (61 AP-12a) are composed of a mineral assemblage similar to that described above. Here again the three aluminum silicate polymorphs, fibrolite and staurolite occur toghether, but a rather discrete distribution of kyanite, staurolite and of the pair fibrolite-sillimanite in different portions of the same area can be observed (Plate E, fig. 3; Plate F, figs. 1, 2). Kyanite, however, also occurs in epitaxial relation with both andalusite and staurolite, as in the rod-shaped volumes described above, and is sometimes fringed with fibrolite needles. Sillimanite, besides being associated with fibrolite, occurs near or within kyanite crystals as scattered prisms, sometimes with the (100) crystallographic plane parallel to the (001) plane of kyanite. Andalusite is randomly distributed as irregular patches, often turbid due to dustly opaque inclusions, with slightly different optical orientation; muscovite inclusions are rather frequent while sillimanite never occurs in it. Also in this occurrence there is no textural proof that andalusite might represent remnants of original porphyroblasts.

In the garnetiferous biotite-muscovite-quartz contact schists (61 AP-14a, 11b) the square-outlined volumes are almost entirely composed of kyanite and subordinately, of muscovite. Staurolite occurs in traces and sometimes few garnet crystals, showing an incipient alteration along fractures, are found (Plate D, fig. 4). Fibrolite, though never being present within the square-outlined areas, often occcurs near their borders as contorted felts intergrown with biotite (Plate F, fig. 4) and is completely lacking in the groundmass at a distance of 1-2 mm from the rims of the areas occupied by kyanite and muscovite.

Finally, the square-outlined areas occurring in the garnetiferous, biotite-muscovite-quartz-staurolite-bearing contact schist (61 AP-14c) also exhibit a rather simple mineral assemblage, being composed of muscovite, which occupies more than 3/4 of each area, of staurolite and minor amounts of kyanite, the latter occurring as irregularly shaped crystals with a corroded appearance and even as droplets included in muscovite flakes. In those areas which show near their borders a new generation of poikiloblastic, coloured andalusite grown toward the groundmass (see above), also fibrolite

and sillimanite occur. Both are mostly present in the nearest periphery of the square-outlined areas; a few fibrolite needles, however, also occur inside these areas included within muscovite flakes.

It is evident that the mineral assemblages found in the rocks containing structural relics of andalusite do not represent either equilibrium parageneses, if the actual mineralogy of the rocks is considered, or products of a single metamorphic episode under unchanged P-T conditions during time. Moreover, shearing stress was also a factor of the metamorphism, because successive deformation phases are often recognizable.

The paragenetic sequence of the minerals either occurring within the rod- and prismatic-shaped volumes and in the groundmass can be tentatively inferred by the textural relationships put into evidence in the description of the thin sections. Not all the textures, however, allow an univoque interpretation, particularly when intergrowths of two minerals are dealt with.

The inferred sequences among the aluminum silicate polymorphs are the following:

(1) andalusite (older, presently occurring as structural relics) → kyanite → sillimanite;

(2) andalusite (younger, now present) → sillimanite;

(3) fibrolite → sillimanite.

Sequence (2) can be surely established only in one case (61 AP-14c) where coloured andalusite occurring near areas formely occupied by andalusite is clearly recognizable as belonging to a distinct and new generation.

The sequence (1) is the best proven and includes the most important feature of the rocks under study, that is the inversion of andalusite to kyanite. The relationships between the sequences (1) and (3) is rather obscure, because no significant textural relation between kyanite and fibrolite can be found, given their discrete distribution in the rocks. This fact, however, could suggest that the two polymorphs grew simultaneously under equilibrium conditions between kyanite and sillimanite, fibrolite being epitaxially nucleated by biotite (Chinner, 1961) (1) kyanite by andalusite.

---

(1) The mechanism of epitaxial growth of fibrolite within biotite proposed by Chinner (1961), involving the addition of Si and Al by the fluid phase can also adequately explain the frequent occurence of fibrolite only near the edge of the volumes formerly occupied by andalusite, from which Al and Si could have been dissolved and transferred by the fluid phase into the nearby groundmass of the rock.

The complete sequence of the aluminum silicate polymorphs should be therefore:

(4) andalusite (older) → kyanite/fibrolite → (younger andalusite?) → sillimanite;

that is a sequence involving a raise in temperature and pressure as a general trend with, possibly, minor fluctuations of the total pressure.

The replacement of andalusite results to be a rather complicated process in detail given the number of chemically different phases occurring in addition to kyanite and sillimanite, particularly staurolite, muscovite and garnet. A redistribution of elements within relatively small rock volume must therefore be postulated to explain the occurrence of staurolite and garnet. Muscovite, on the other hand, which is likely to have recrystallized at a partial expense of the aluminium silicates, should be related to high activity of H_2O and K at a late stage of the replacement process, the source of K being probably external, that is the fluid phase from the adjacent magmatic body.

If the whole texture of the rocks are considered it seems probable that a large amount of staurolite, or perhaps all the staurolite which composes small porphyroblasts occurring in the groundmass outside of the rod- and prismatic-shaped volumes were formed after the inversion of andalusite to kyanite. The same seems probable for the garnet which composes inclusion-free borders around dustly cores of the garnet porphyroblasts within the groundmass.

Two main phases of deformation are clearly recognizable. The earlier pre-crystalline phase produced a well-developed foliation which is largely preserved in the actual fabric. A later, largely post-crystalline, minor phase produced local folding and slight rotation of pre-existing porphyroblasts (see page 253). Crystallization of biotite alone outlasted the formation of the folds. The lineation which governed the growth of andalusite porphyroblasts as oriented rod-shaped individuals could doubtly be referred to as a pre-crystalline tectonic feature.

Summarizing on, the following phases and stages can be recognized in the metamorphic history of the contact schists of the Lake Shiwa area:

(1) An earlier low-grade regional metamorphism which converted the pelitic rocks into slates;

(2) The second and main phase, connected with the emplacement of the granite and granodiorite intrusive was essentially a thermal metamorphism under relatively high pressure, not unlike that of a regional metamorphism (HESS, 1969). The P-T conditions during the whole phase were probably very close to the triple point of the $Al\ Si_2O_5$ system (about 5,5 kb and 622°C according to RICHARDSON, GILBERT & BELL, 1969) the temperature and, perhaps to a lesser extent, the pressure having raisen over a restricted interval around the triple point. At a first stage andalusite, toghether with micas and some garnet, were formed. An uprise of temperature and pressure, or, according to HOLLISTER'S (1969) suggestion of metastable crystallisation of andalusite in the kyanite stability field, only of temperature, caused the inversion of andalusite to kyanite and concurrently the formation of fibrolite, followed, by recrystallization, by sillimanite and of most of the staurolite, some garent having crystallized when the highest temperatures were reached.

The occurrence of a new generation of andalusite cannot be satisfactory explained with the available data. Whether this andalusite represents a metastable phase, or crystallized in equilibrium with both kyanite and fibrolite remains an open question.

The final, generally poorly represented mineralogical transformations occurring in the group of rocks under study, that are, the probable regeneration of staurolite, the crystallization of muscovite at a partial expense of the aluminum silicates, and at a very late stage, the chloritization of garnet, can be referred to as a retrograde metamorphism.

(3) The third metamorphic phase was characterized by a slight deformation, which produced folding, and by the sin- to post-tectonic crystallization of biotite connected with it, clearly post-dating the main metamorphic phase (2), except probably its very late stages. The shearing stress which acted during this phase could have been caused by deformations which accompanied the intrusion of the igneous rocks at some stage of the intrusive episode occurred in the region.

3. ON THE ABSOLUTE AGE OF SOME ROCKS.

Determination of absolute age of minerals (muscovite and biotite) by the Rb/Sr method on three samples of rock from the Lake Shiwa area gave rather uniform data, between 17 M.Y. and 23 M.Y. (page 217).

Only one of the dated samples belong to the migmatite complex: it is a garnet-bearing biotite-oligoclase-orthoclase gneiss (61 AP-17/3) representative of the types less altered by granitization occurring among the banded gneiss. The age of the biotite in the rock is 23 M.Y. In the two other samples (61 AP-17/19 and 61 AP-17/25) the age of the muscovite was determined. Both samples come from the mylonite belt. The first sample (61 AP-17/19) is a mylonite garnet and tourmaline-bearing pegmatite (see page 240), moderately recrystallized under conditions of low-grade metamorphism. The muscovite occurring as large flakes is strongly deformed and some white mica (sericite and muscovite as small flakes) is present as an alteration product of plagioclase and of garnet.

The other sample (61 AP-17/25) is also characterized by blastomylonitic texture. The rock was interpreted as a cataclastically deformed and laminated garnet-muscovite aplite. Muscovite occurs chiefly as large oriented and bent laminae and as plumose aggregates fringing larger crystals. It can be assumed that at least a partial recrystallisation of muscovite accompanied the final dynamic metamorphism.

The absolute age of the muscovite, therefore, can provide only a minimum age, probably only a chronological framing of the dynamic metamorphism which affected the rocks, showing it to be of Alpine age (1). Unfortunately no absolute age of the massive granites and granodiorites was determined, because of the strong weathering of the biotite in all the samples.

The absolute age of the biotite in the sample 61 AP-17/3 is expected to provide a more direct chronological reference for the main stage of metamorphism of the rock. Biotite, which is very abundant in this rock, seems to belong to a single generation. There is textural evidence that crystallization of biotite took place during the main phase of deformation and migmatization of the rock, and outlasted the deformation movements.

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(1) The relative geological age corresponding to the absolute dates is Miocene (Desio, Tongiorgi & Ferrara, 1964).

4. PETROGENETIC PROBLEMS CONNECTED WITH THE METAMORPHIC AND IGNEOUS ROCKS.

4.1 Migmatite Complex.

Summary of Rock-types. — Leucocratic banded gneiss granodioritic in mineral composition represent the predominant rock type in the migmatite complex. It is moderatelly heterogeneous, often feldspar porphyroblastic, and contains biotite as predominant mafic minerals; a few banded gneiss contains additional garnet or hornblende associated with biotite (Fig. 31).

Augen gneiss, rather variable in texture, and granitic in mineral composition and gneissose pegmatite are also important components of the migmatite complex.

Non granitic (sensu stricto) rocks, include metagabbro, and various amphibolites, themselves mostly, or possibly all, meta-intrusive. These rocks, which can be considered as remnants, provide but few informations about the parent material of the migmatite complex, the parent rocks or the pure metamorphic equivalent of the predominant banded gneiss and augen gneiss not occurring in the migmatitic sequence.

The leucocratic more or less biotite-rich plagioclase gneiss, interpreted as derived from paragneiss by plagioclase blastesis and, possibly by silica and soda metasomatism, occurs in moderate amount within the migmatite complex. This rock, however, seems to be of overall importance to investigate genetic relationships in view of their analogies with many banded gneisses.

The dominant pattern in the migmatite is banding and layering; well definited bands are generally composed either of basic rocks either of gneissose pegmatite. The latter, particularly, mostly occur as concordant bands or flattened lenses, that are as largerly synkinematic bodies.

Petrographical Features. — The available field and petrographic data do not permit a comprehensive interpretation of the petrogenetic process which gave rise to the migmatite complex. On one hand the areal extent of the migmatite, particularly to the east of the surveyed territory, is unknown to us and data about the country rocks are lacking; on the other hand the interpenetration structures of the migmatite make it difficult in most

cases even a distinction between paleosome and neosome, that is to ascertain the composition of their mobile components.

The contribution provided by the petrographic study to a genetic interpretation can be summarized in the following observations:

1) The most apparent petrographic feature exhibited by banded gneiss and augen gneiss is a widespread K-feldspar mobilization. There is textural evidence that the potash feldspar largely replaced plagioclase (antiperthites were also locall produced) and quartz.
2) Also in gneissose pegmatite the potash feldspar is seen replacing the plagioclase.
3) The potash feldspar content increases from more and more homogeneous leucocratic banded gneiss to augen gneiss; concurrently the shape of the potash feldspar crystals becomes more and more idioblastic to porphyroblastic in augen gneiss.
4) The potash feldspar is mostly represented, in every occurrence, by orthoclase, which shows relatively small, and variable, axial angle. Microcline, occurring as ill-defined patches within potash feldspar porphyroblasts, could be interpreted as secondary after orthoclase, and possibly related with late deformation movements. It is therefore suggested that the primary potash feldspar crystallized at high temperature and behave during the metamorphic history of the rocks as a relatively stable phase.
5) The crystallization of potash feldspar appears to be essentially synkinematic with respect to the main act of deformation. Later deformation movements, which left their imprint in almost all the rocks of the migmatitic sequence, were accompanied by the development of myrmekite, often very abundant, and representing another prominent feature of banded gneiss, augen gneiss and of gneissose pegmatite and by a partial mobilization of quartz. The final event was a weak cataclasis followed by deposition of low-temperature minerals, chiefly albite and quartz, that is a diaphtoritic process.
6) The variety of structural and textural features of the plagioclase gneiss, are represented in a somewhat similar manner in most banded gneiss and augen gneiss. This is true particularly for the occurrence and composition of the plagioclase. Though no definitive proof can be offered, it seems conceivable that plagioclase blastesis (soda-silica metasomatism)

represents a general process which affected the whole migmatite sequence and preceded the potash feldspar mobilization. This hypotesis should imply that the main migmatization process, of which there is petrographical evidence, affected already metamorphosed and perhaps migmatized rocks.

4.2. Cataclastic and Blastomylonitic Granite and Granodiorite.

The most important feature of the rocks belonging to the second unit recognized in the field (complex of cataclastic and blastomylonitic granitoid rocks, aplite and pegmatite associated with metagabbro and paraschists) is their high degree of mechanical deformation associated with a more or less pronounced recrystallization, as a result of which the rocks became tectonites.

The intensity of cataclasis and lamination varies considerably, and is less marked in the basic than in the granitoid rocks. Deformation generally decreases both with passage to the migmatite complex and towards the area of massive granite and granodiorite.

In the mylonitic types deformation is evident in the lamination of the matrix, prevalently of quartz and in the concurrent cataclasis of the large feldspars. Later cataclasis belonging to a subsequent phase of deformation, is often present.

The blastomylonitic granitoid augen gneiss occurring near the migmatite complex is largely recrystallized, and no retrograde change occurs in biotite and plagioclase notwithstanding the intensity of the deformation. Potash feldspar is weakly deformed and largely diffused in the matrix toghether with abundant myrmekite. For these features the rocks can be considered as highly deformed equivalents of the augen gneiss occurring in the migmatite complex.

The cataclastic to blastomylonitic granitoid rocks and the massive aplite and pegmatite occurring near the transition zone to granite and granodiorite contain only low-temperature minerals as recrystallized components and show a more or less pronounced diaphtoritic changes of the primary components.

In spite of the general imprint of a dynamic metamorphism and the

absence of primary contacts it seems probable that rocks genetically related either to the migmatites either to the intrusives which follow westwards compose the sequence of strongly deformed rocks. Particularly the blastomylonitic, more or less diaphtoritic, augen gneisses and the associated pegmatite, and aplites (both very different from the pegmatoid occurring in the migmatite complex), and the metadiorite could represent the marginal sheared zone of the intrusive granite and granodiorite, the different rock types having possibly been intruded at different stages. In this respect the strips of garnet-sillimanite contact schist could represent dislocated rafts or enclaves of Black Slates which cover to the east the granite and granodiorite. The question wether the main stage dynamic metamorphism post-dated the whole intrusive episode or took place at some late stage in the history of emplacement cannot be solved by the available data. The second hypothesis is preferred, being somewhat supported by the occurrence of a multiple-phase metamorphism in the contact schists occurring along the western contact of granite and granodiorite.

4.3. Baharak Granodiorite.

There is evidence by field observations (existence of sharp contacts with Black Slates, either in case of smooth contacts, either if the country rocks are penetrated by veins of igneous material; occurrence of minor sharply limited intrusive bodies) and by the type of metamorphism produced in the adjacent country rocks, that the emplacement of the granite-granodiorite intrusive of the Lake Shiwa area took place, at least partly, by magmatic intrusions. This necessary implies a deeper, or possibly distant source of magma. In outline, the occurrence of the intrusive rocks between two units different in lithology and metamorphic history could answer of the contrasting situation at their western and eastern contacts.

The suggestion by the aluminum silicates parageneses in the contact schists derived from Black Slates, of rising pressure during the metamorphism around the triple point of the Al_2SiO_5 system implies, according to experimental data, that the total pressure reached a maximum value greater than 5,5 kb. This datum seems to be somewhat immaterial to infer accu-

rately the depth of intrusion since a gas or a tectonic overpressure cannot in principle be disregarded.

TABLE 4 a - Modal analyses (volume %) of amphibolites from the migmatite complex (1).

Specimen	61 AP-17/4	61 AP-17/5	61 AP-17/14
Quartz	0,7	11,6	6,1
Plagioclase	35,1	29,5	39,4
Biotite	2,2	7,8	30,5
Hornblende	58,5	34,7	16,9
Pyroxene	0,6	—	—
Garnet	0,1	9,5	—
Sphene	0,7	—	4,8
Chlorite	—	—	tr.
Accessories	2,1	6,9	2,3
Total	100,0	100,0	100,0

TABLE 4 b - Modal analyses (volume %) of plagioclase-biotite gneisess from the migmatite complex.

Specimen	61 AP-17/12	61 AP-17/13	61 AP-17/6
Quartz	25,2	37,8	42,3
Plagioclase	46,3	46,6	50,6
Potash feldspar	—	—	0,1
Biotite	25,5	15,0	6,9
Accessories	3,0	0,6	0,1
Total	100,0	100,0	100,0

(1) The modal analyses reported in Tables 4 a-g were made by the point-counter in those rocks which were more homogeneous, and in slides cut normal to the foliation. 1000-1500 point were counted from each slide.

TABLE 4 c - Modal analyses (volume %) of leucocratic finely banded gneisses from the migmatite complex.

Specimen	61 AP-17/3	61 AP-17/1	61 AP-17/11
Quartz	41,1	37,1	36,5
Plagioclase	19,9	38,7	49,4
Potash feldspar	15,4	14,3	9,6
Myrmechite	9,7	1,6	0,6
Albite (late)	—	—	0,6
Biotite	13,2	7,6	2,4
Chlorite	—	0,7	0,5
Accessories	0,7 *	tr.	0,4
Total	100,0	100,0	100,0

* incl.: garnet.

TABLE 4 d - Modal analysis (volume %) of a granitic augen gneiss from the migmatite complex. Sample 61 AP-17/8.

Quartz	Plagioclase	K-Feldspar	Myrmechite	Biotite	Chlorite + Fe oxides	Total
35,5	23,5	31,8	4,1	2,9	2,2	100,0

TABLE 4 e - Modal analyses (volume %) of granitoid augen gneiss (blastomylonitic p.p.).

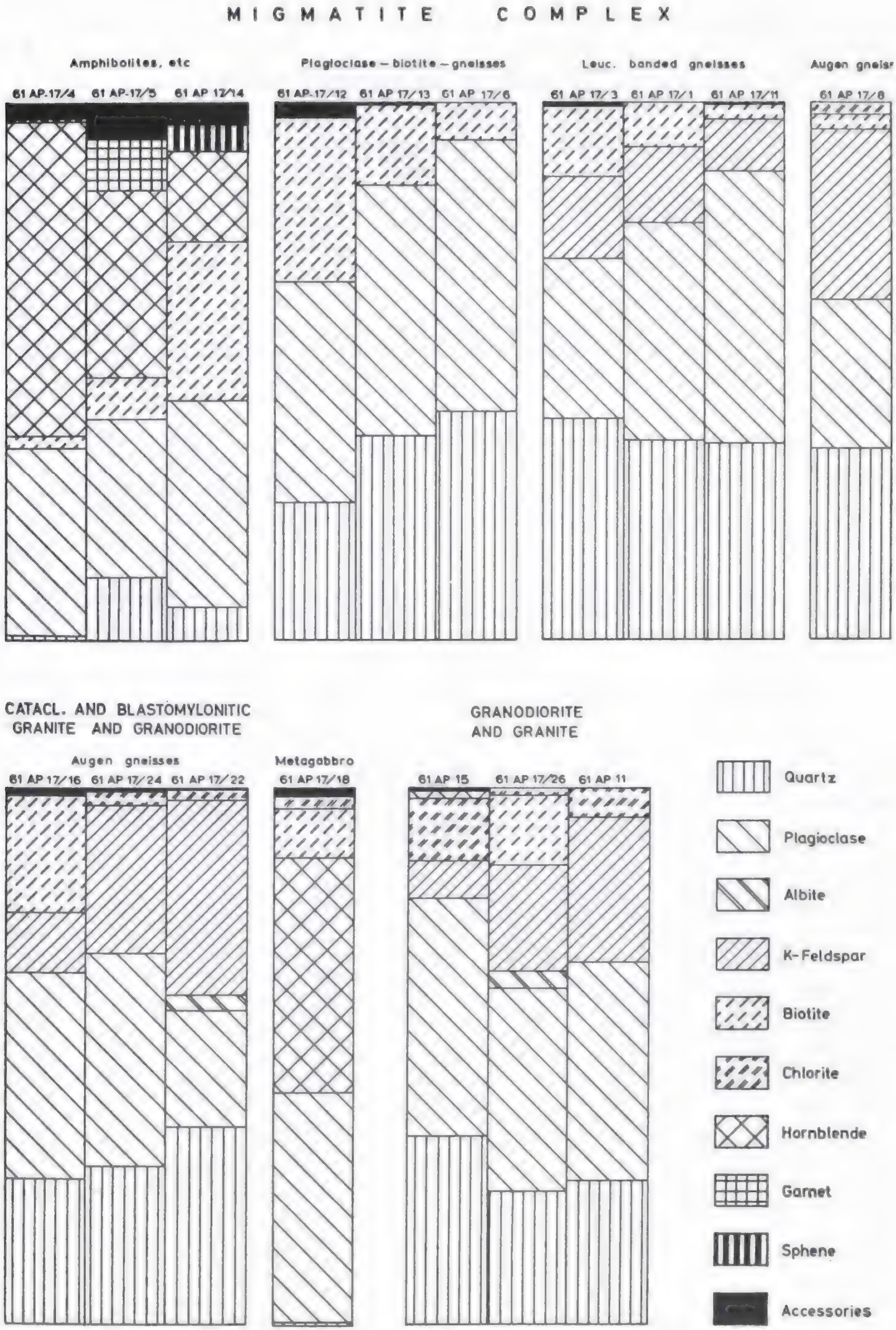
Specimen	61 AP-17/16	61 AP-17/24	61 AP-17/22
Quartz	27,3	29,6	37,0
Plagioclase	35,5	39,1	21,8
Potash feldspar	11,2	27,5	36,3
Myrmechite	2,9	—	—
Albite	—	0,7	2,7
Biotite	21,8	—	—
Chlorite + Fe oxid.	tr.	2,4	1,9
Accessories	1,3	0,7	0,3
Total	100,0	100,0	100,0

Table 4 f - Modal analysis (volume %) of a metagabbro from a basic band within blastomylonitic augen gneiss. Sample 61 AP-17/18.

Quartz	Plagioclase	Hornblende	Biotite	Chlorite + Fe oxides	Accessories	Total
0,6	42,8	43,6	9,3	2,3	1,4	100,0

Table 4 g - Modal analyses (volume %) of granodiorite and granite.

Specimen	61 AP-15	61 AP-17/26	61 AP-11
Quartz	35,2	24,7	26,8
Plagioclase	44,4	36,7	35,3
Potash feldspar	7,0	19,9	27,1
Myrmechite	—	1,3	5,4
Albite	—	3,2	—
Biotite	—	12,8	—
Chlorite + Fe oxid.	11,5	1,2	5,1
Hornblende	1,1	—	—
Accessories	0,8	0,2	0,3
Total	100,0	100,0	100,0


MIGMATITE COMPLEX
Amphibolites, etc
Plagioclase – biotite – gneisses
Leuc. banded gneisses
Augen gneiss
61 AP-17/4
61 AP-17/5
61 AP 17/14
61 AP-17/12
61 AP 17/13
61 AP 17/6
61 AP 17/3
61 AP 17/1
61 AP 17/11
61 AP 17/8
CATACL. AND BLASTOMYLONITIC GRANITE AND GRANODIORITE
Augen gneisses
61 AP 17/16
61 AP 17/24
61 AP 17/22
Metagabbro
61 AP 17/18
GRANODIORITE AND GRANITE
61 AP 15
61 AP 17/26
61 AP 11
Quartz
Plagioclase
Albite
K-Feldspar
Biotite
Chlorite
Hornblende
Garnet
Sphene
Accessories

PETROGRAPHIC THIN SECTIONS OF THE LAKE SHIWA AREA.

PLATE A

Basic rocks and plagioclase-biotite gneisses from the migmatite complex

Fig. 1. - *Metagabbro* (61 AP-17/4).

(Plane polarized light; $\times$ 38).
The essential components are plagioclase and hornblende; augite (Py) and garnet (Gr) occur among the accessories.

Fig. 2. - *Biotite-amphibole schist* (61 AP-17/14).

(Plane polarized light; $\times$ 30).
The mineral assemblage is biotite, hornblende (poikilitic), plagioclase, quartz and sphene.

Fig. 3. - *Biotite-plagioclase gneiss* (61 AP-17/12).

(Crossed Nicols; $\times$ 27).

Fig. 4. - *Plagioclase-biotite gneiss* (61 AP-17/6).

(Crossed Nicols; $\times$ 14).
A noteworthy increase in grain size of the plagioclase crystals is concurrent with the decrease of the biotite content from more mafic (61 AP-17/12; fig. 3) to less mafic (61 AP-17/6; fig. 4) plagioclase-biotite gneiss. The texture of both rocks shows effects of late deformation.

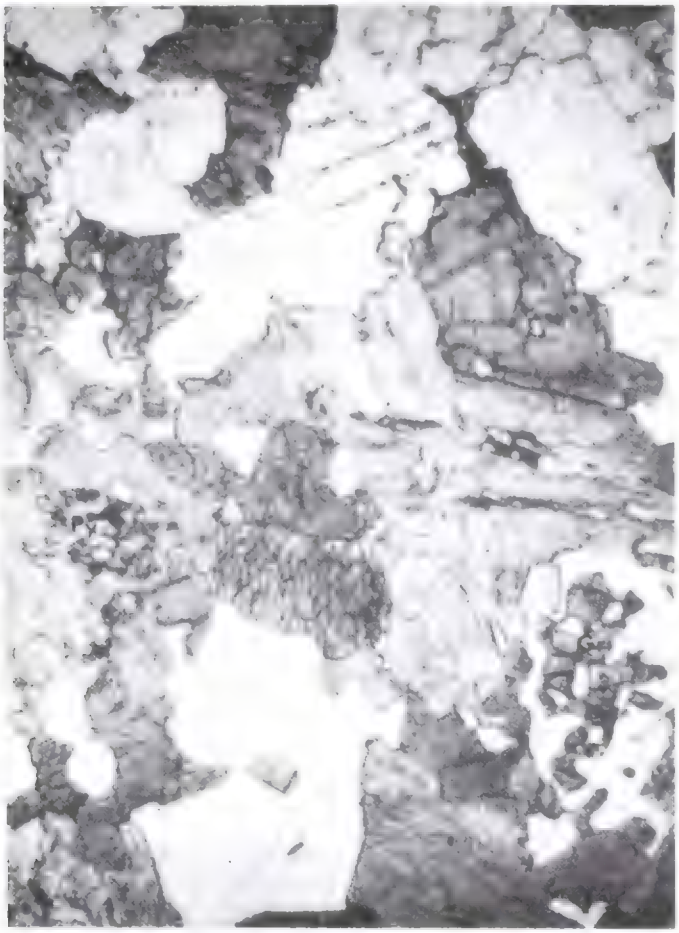


Fig. 1.

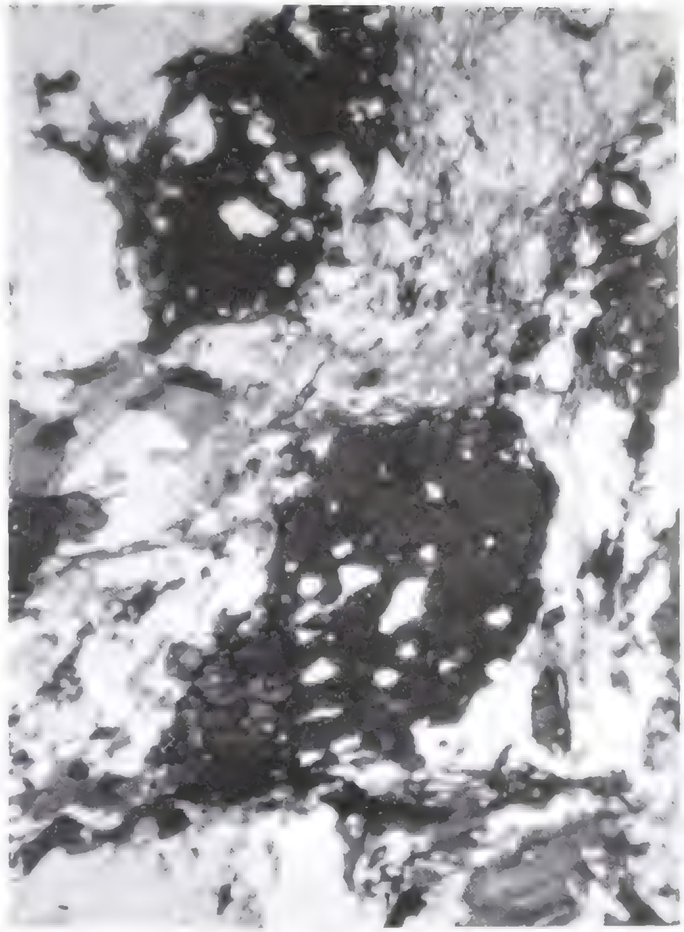


Fig. 2.

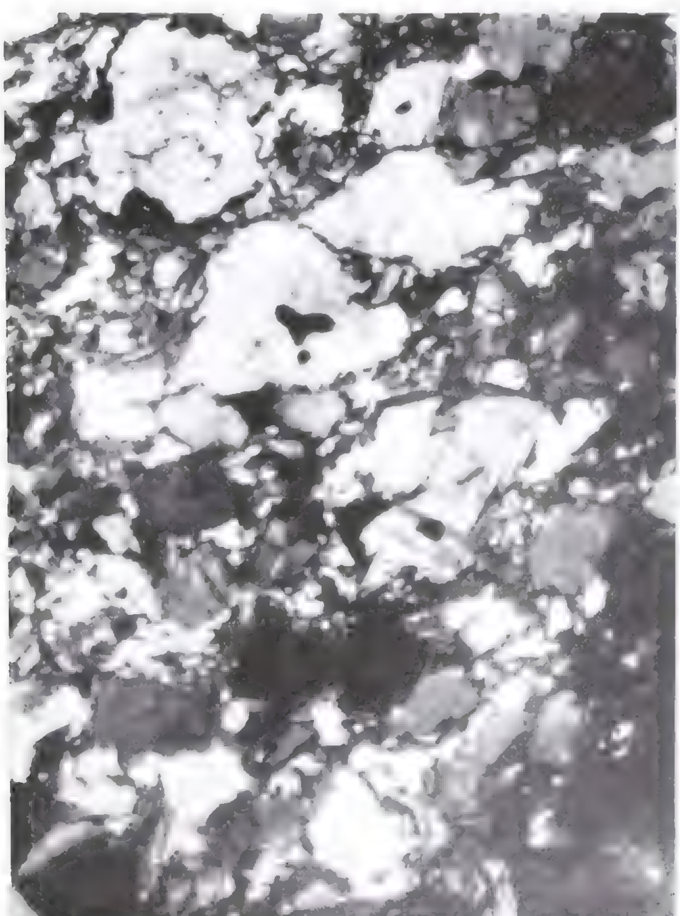


Fig. 3.

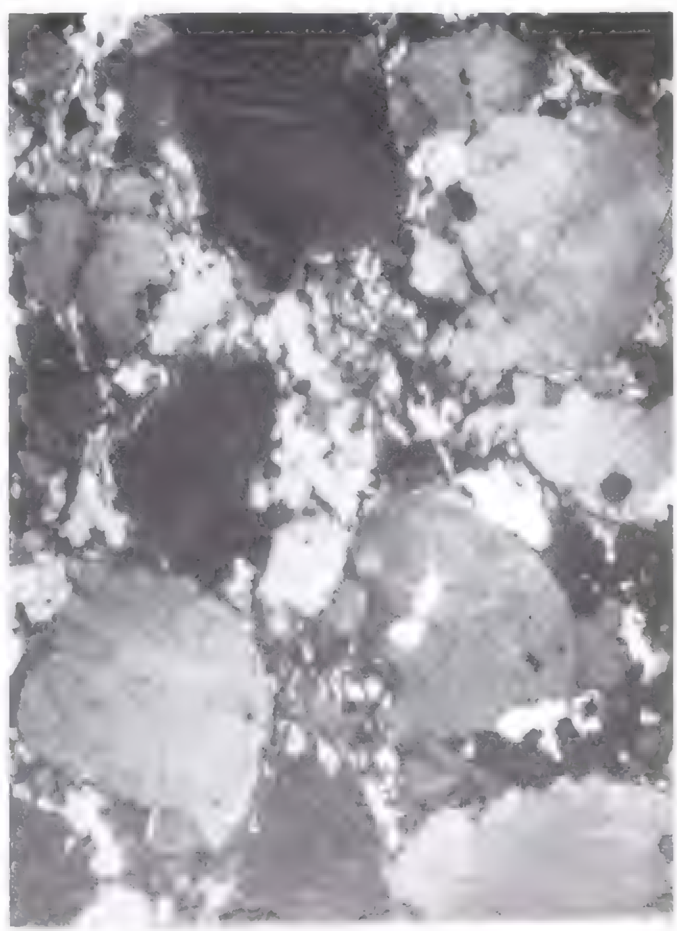


Fig. 4.

PLATE B

Leucocratic banded gneissen and augen gneiss from the migmatite complex

Fig. 1. - *Garnet-bearing biotite-oligoclase-quartz-orthoclase gneiss* (61 AP-17/3).
(Plane polarized light; × 38).

Fig. 2. - *Biotite-hornblende-oligoclase-quartz-orthoclase gneiss* (61 AP-17/7).
(Plane polarized light; × 27).

Microfabric of striped gneisses showing more (fig. 2) or less regularly (fig. 1) alternating dark streaks and light layers, the latter composed of quartz (Qz), plagioclase (Pl) and interstitial orthoclase (Kf). Replacement antiperthites occurring in plagioclase may be seen in fig. 1 (middle left).

Fig. 3. - *Augen gneiss* (Specimen 61 AP-17/9; × 0,8).

Feldspathic eyes and lenses, in which potash feldspar is predominant, stand out against a dark groundmass relatively rich in biotite. The growth of the eyes and lenses is attributable chiefly to metamorphic differentiation.

Fig. 4. - *Augen gneiss* (61 AP-17/9).
(Crossed Nicols; × 7).

A small eye occurring in the specimen figured in the preceding photograph is composed of orthoclase (dark grey areas) partly transformed to microcline (lighter areas showing a vague cross-hatched pattern) and is surrounded by myrmechite grains. Replacement quartz occurs.

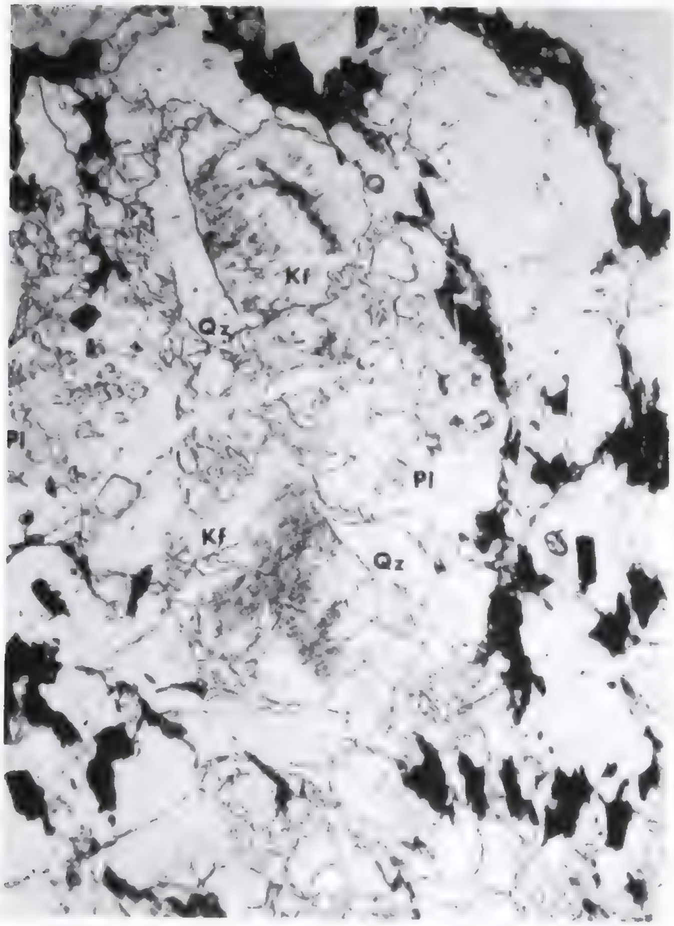


Fig. 1.

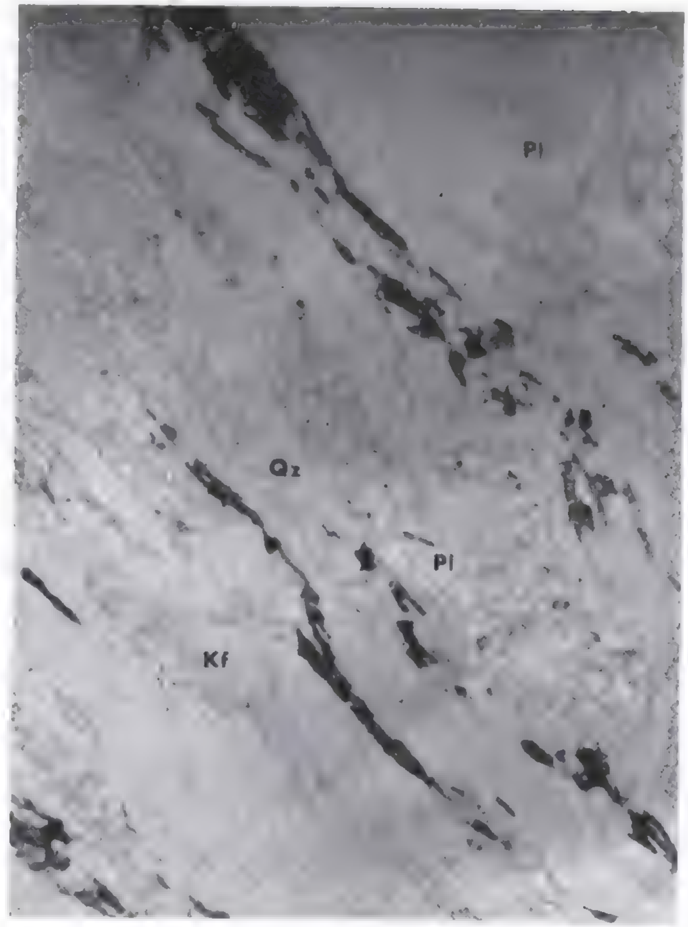


Fig. 2.

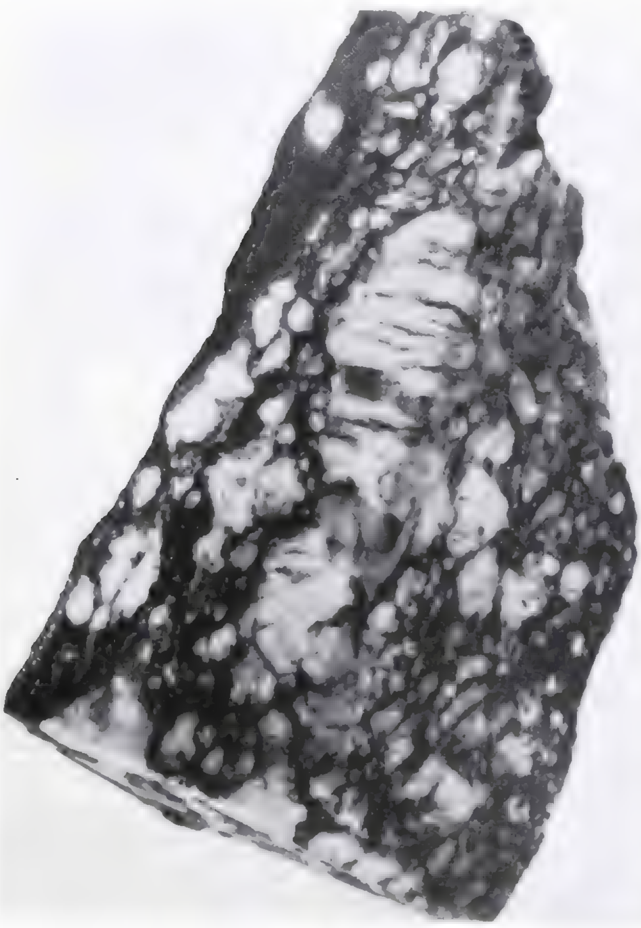


Fig. 3.

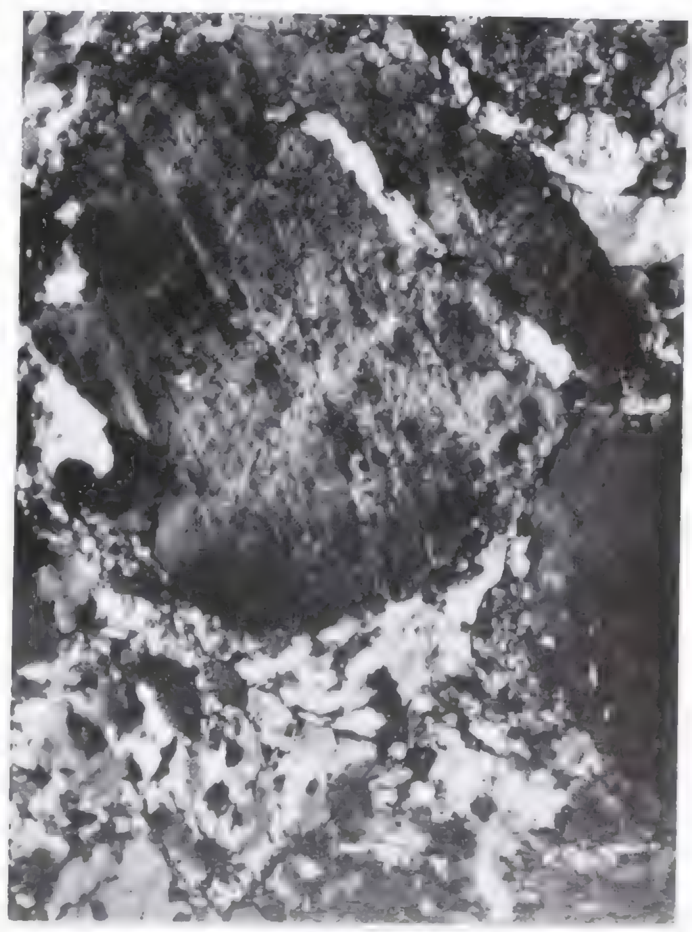


Fig. 4.

PLATE C.

AUGEN GNEISSES AND PEGMATITE FROM THE BLASTOMYLONITIC GRANITE AND GRANODIORITE

Fig. 1. - *Blastomylonitic augen gneiss* (61 AP-17/20).
(Crossed Nicols; × 8).

Strained and fractured porphyroclasts of plagioclase and microcline are included in a fine-grained laminated matrix of quartz, feldpars and biotite. A pseudoschistose quartz layer may be seen in the middle of the photomicrograph.

Fig. 2. - *Blastomylonitic pegmatite* (61 AP-17/19).
(Crossed Nicols; × 30).

The rock is composed essentially of quartz, plagioclase and microcline; it contains altered garnet and tourmaline (of which a broken crystal recemented by quartz is figured bottom left of the photomicrograph) in addition.

Fig. 3. and 4. - *Blastomylonitic augen gneiss* (61 AP-17/16).
(Crossed Nicols; fig. 3: × 18; Fig. 4: × 134).

A slightly deformed potash feldspar porphyroblast, enclosing at its rim more or less apparent myrmechite, shows along one edge a granular border (detailed in fig. 4) which penetrates into the groundmass and partially replaces it.

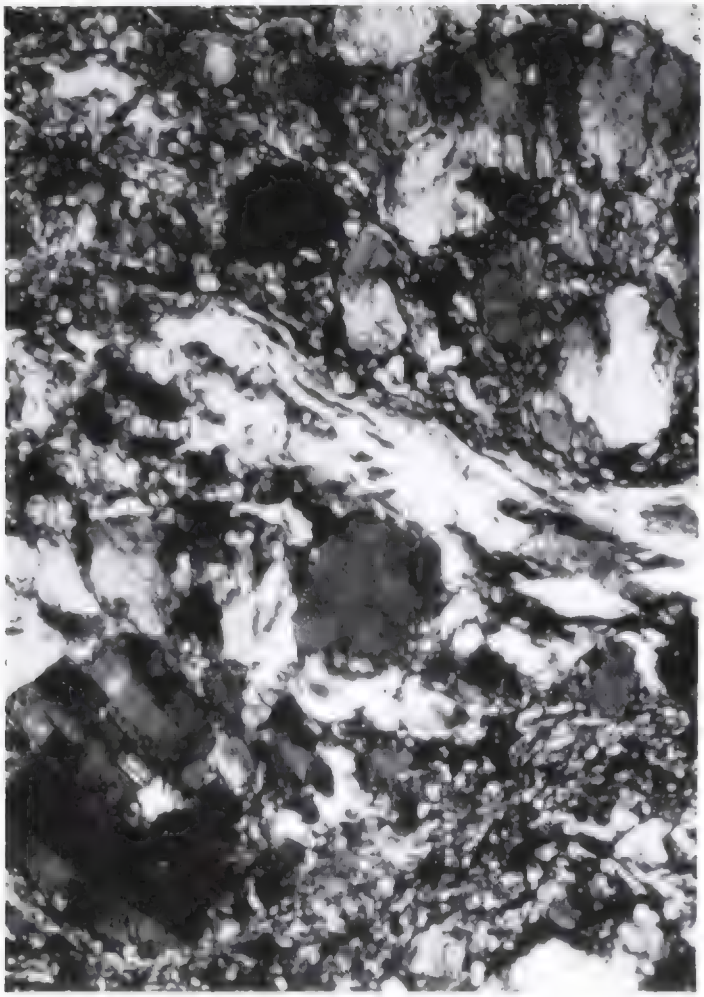


Fig. 1.

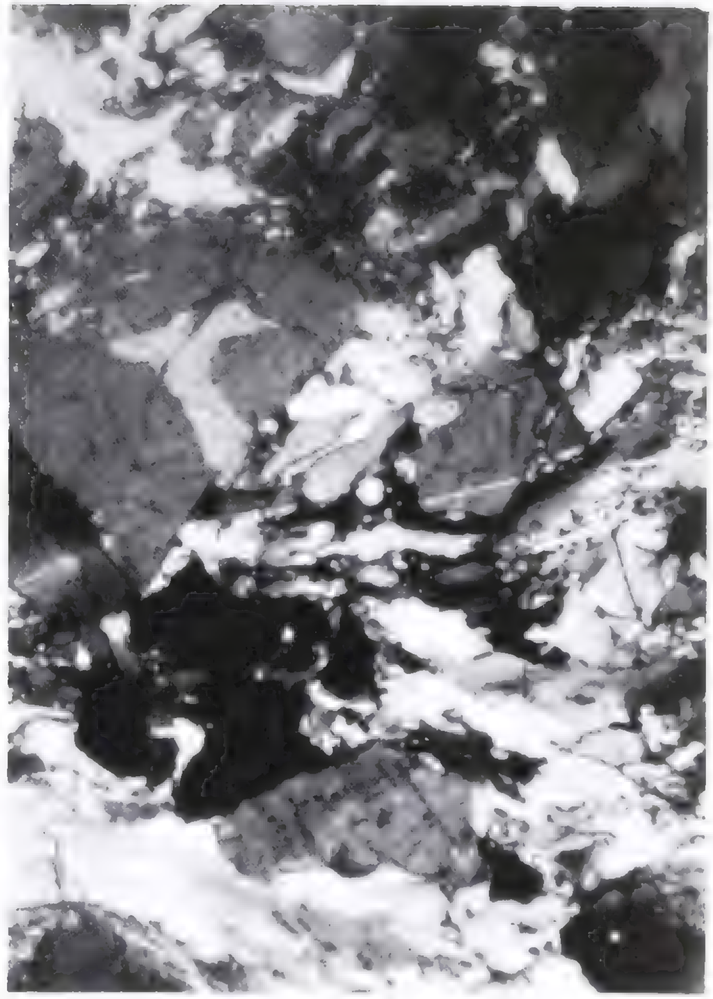


Fig. 2.

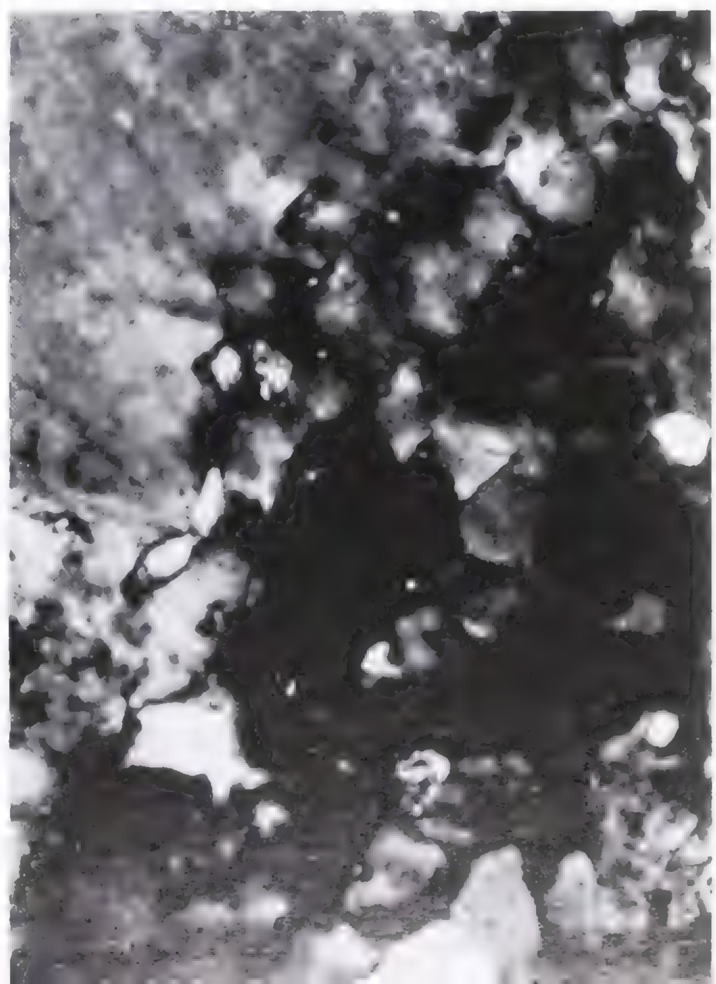


PLATE D

ANDALUSITE STRUCTURAL RELICS IN ALUMINUM SILICATES-BEARING CONTACT SCHISTS DERIVED FROM BLACK SLATES

Fig. 1. - *Garnet- and staurolite-bearing quartz-biotite-muscovite-graphite contact schist with andalusite structural relics.* (Specimen 61 AP-12 a; × 2,1).

An aggregate of kyanite, muscovite, staurolite, sillimanite and andalusite composes a prismatic-shaped volume with cruciform section formerly occupied by an andalusite porphyroblast (probably chiastolite), within a dark, fine-grained schistose matrix.

Fig. 2. - Microfabric of a cruciform-outlined area formerly occupied by andalusite (61 AP-12 a). (Negative print from thin section; × 6,4).

An original andalusite porphyroblast has been replaced by kyanite (Ky), staurolite (St), muscovite (Ms); fibrolite, sillimanite and andalusite which also occur within the figured area cannot be distinguished in the photomicrograph.

Fig. 3. and 4. - Microfabric of cruciform- and square-autlined areas formerly occupied by andalusite (61 AP-14 a). (Fig. 3: negative print from thin section; × 4,8. Fig. 4: plane polarized light: × 27).

Original andalusite porphyroblasts have inverted to kyanite (Ky) occurring as sheaf-like aggregates. Within the areas formerly occupied by andalusite muscovite (Ms) and garnet (Gr; detail in fig. 4) occur.

Fig. 1.

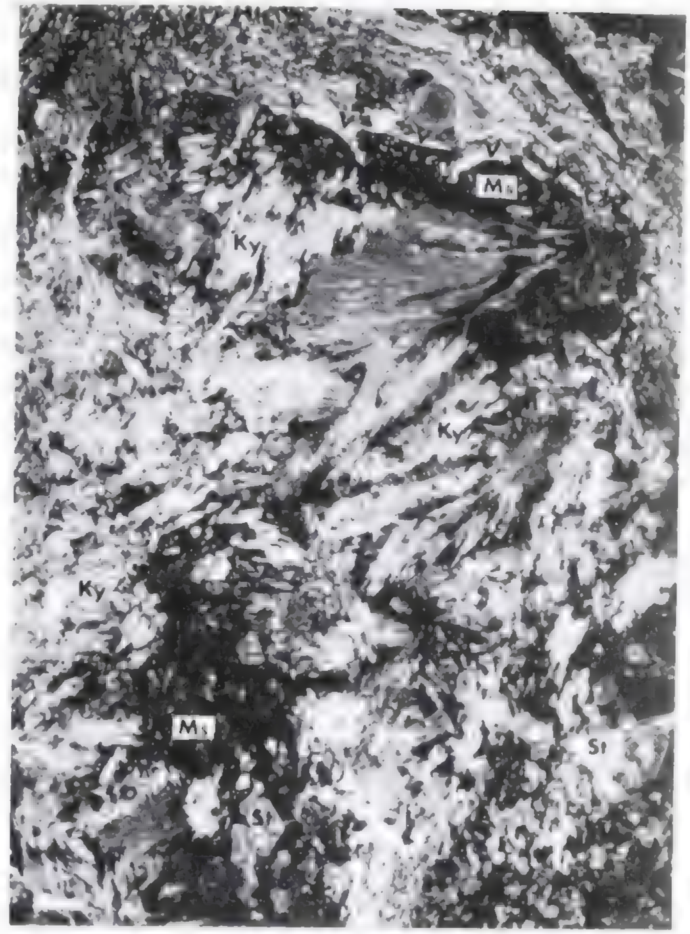


Fig. 2.

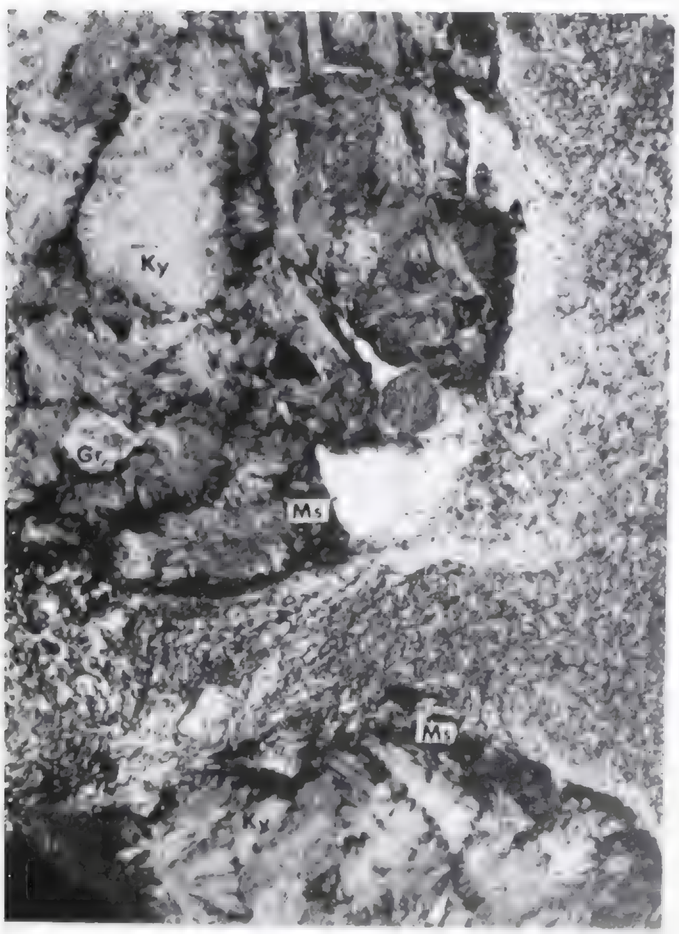


Fig. 3.

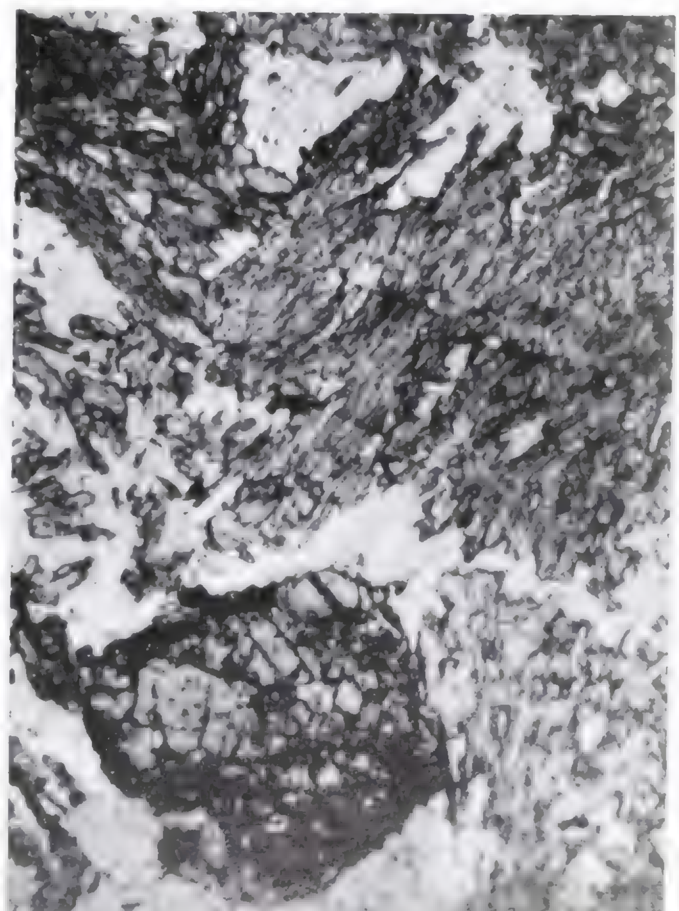


Fig. 4.

PLATE E

SECOND GENERATION ANDALUSITE IN CONTACT SCHISTS CONTAINING ANDALUSITE STRUCTURAL RELICS

Fig. 1. and 2. - *Garnet- and andalusite-bearing biotite-muscovite-quartz-graphite contact schist* (61 AP-14 c). (Fig. 1: negative print from thin section; × 12. Fig. 2: plane polarized light; × 37).

Poikiloblasts of coloured andalusite (Ad) have grown near the edges of a volume formerly occupied by andalusite, which is composed of muscovite (Ms), staurolite and of scarce relict kyanite. A tectonic phase post-crystalline with respect to the new andalusite caused folding and slight rotation of the prismatic-shaped volume. Recrystallization of biotite (Bi) outlasted the deformation.

FIBROLITE OCCURRING WITHIN AND NEAR SQUARE- AND CRUCIFORM-OUTLINED AREA FORMERLY OCCUPIED BY ANDALUSITE

Fig. 3. - *Contact schist with andalusite structural relics* (61 AP-12 a). (Plane polarized light; × 85).

Within a cruciform-outlined area, near its border, fibrolite occurs intimately associated with some biotite as mats of fine needles. Staurolite (St) and muscovite (Ms) are also present.

Fig. 4. - *Contact schist with andalusite structural relics* (61 AP-14 a). (Plane polarized light; × 85).

Kyanite and fibrolite occur respectively inside and outside of a square-outlined area near its margin.

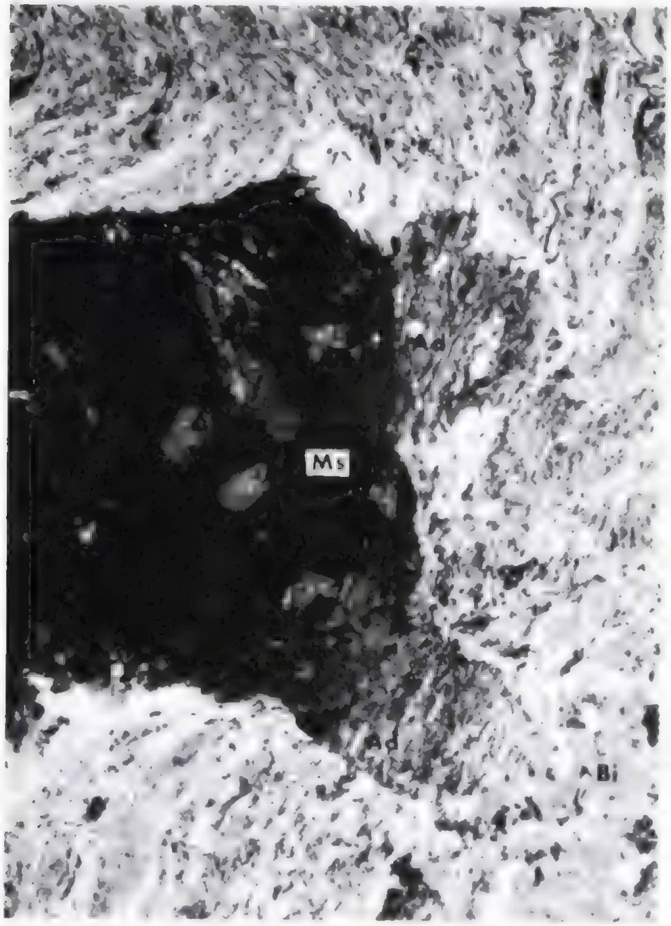


Fig. 1.

Fig. 2.

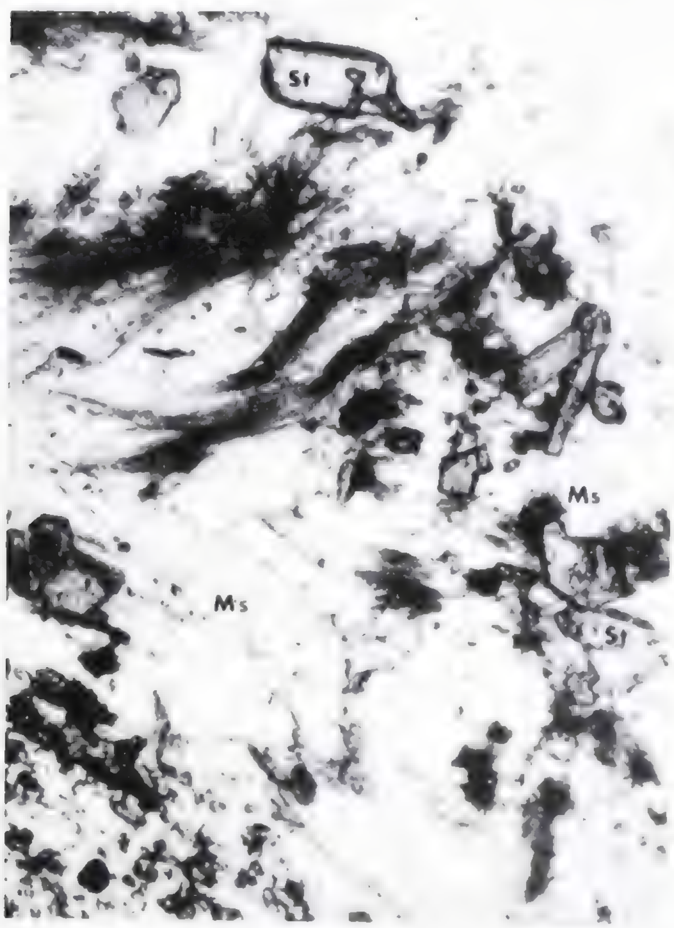


Fig. 3.

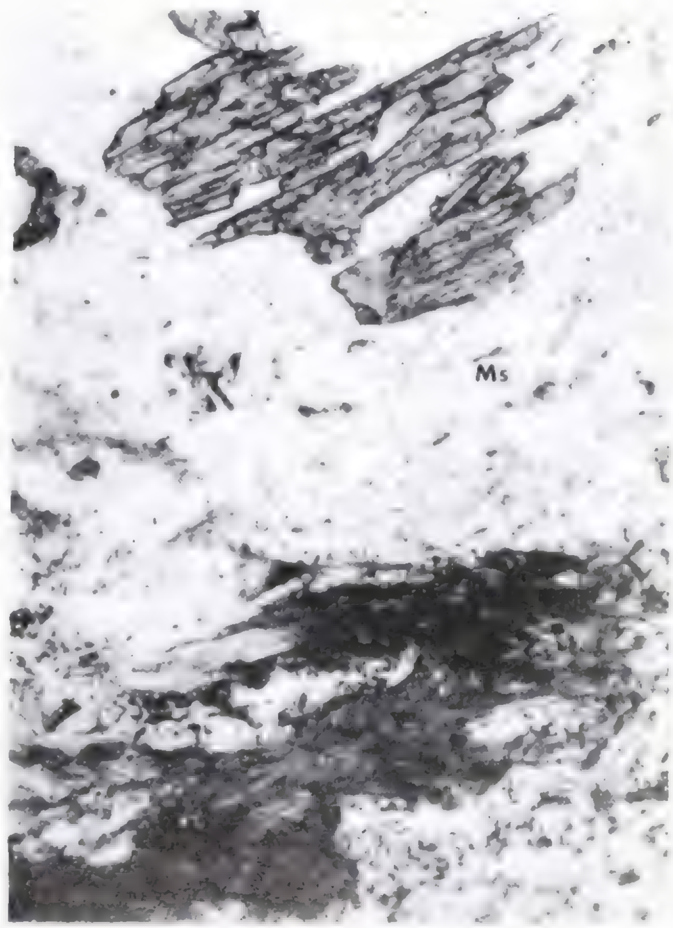


Fig. 4.

PLATE F

TEXTURES OF ALUMINUM SILICATES AND OF STAUROLITE OCCURRING WITHIN ROD- AND PRISMATIC-SHAPED VOLUMES FORMERLY OCCUPIED BY ANDALUSITE IN CONTACT SCHIST DERIVED FROM BLACK SLATES.

Fig. 1. and 2. - Kyanite, staurolite and sillimanite in different occurrences within a cruciform-outlined area (61 AP-12 a).
(Plane polarized light; fig. 1: $\times$ 37; fig. 2: $\times$ 136).

In the same area kyanite (Ky) and staurolite (St) occur either side by side as separate crystals (fig. 1), either in an epitaxial relation (fig. 2). Also sillimanite (Sil) is probably in an epitaxial relation with kyanite (fig. 2).

Fig. 3. and 4. - Andalusite, kyanite, fibrolite, sillimanite and staurolite in rod-shaped volumes derived from andalusite (61 AP-12).
(Plane polarized light; fig. 3: $\times$ 85; fig. 4: $\times$ 136).

Kyanite (Ky) and andalusite (Ad) occur in an epitaxial relation; nearby also fibrolite (Fb) associated with sillimanite (Sil) are present (fig. 3). Within rod-shaped volumes sillimanite mostly occurs toghether with fibrolite in close association with staurolite (St) (fig. 4).

Fig. 1.

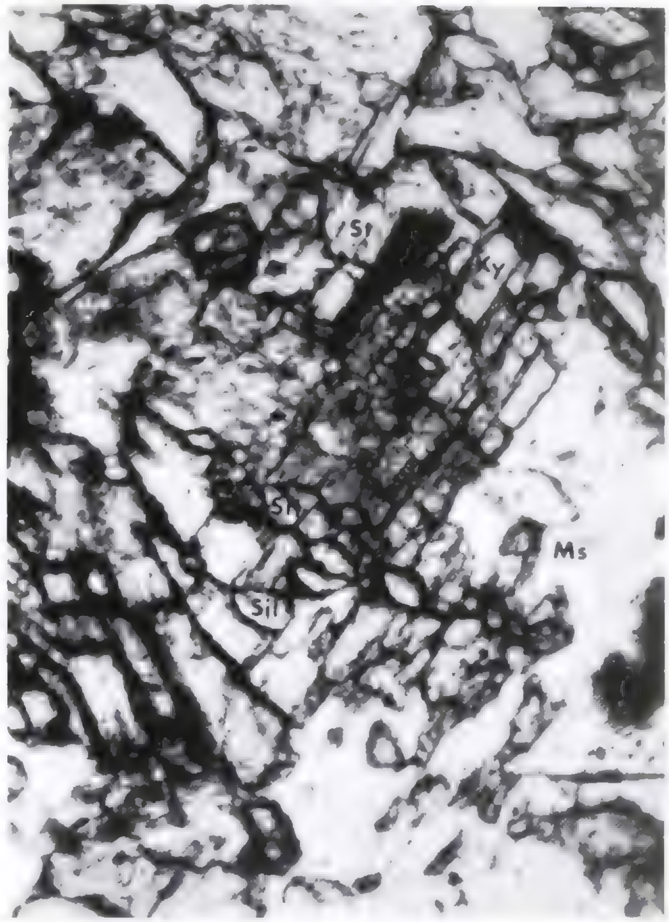


Fig. 2.

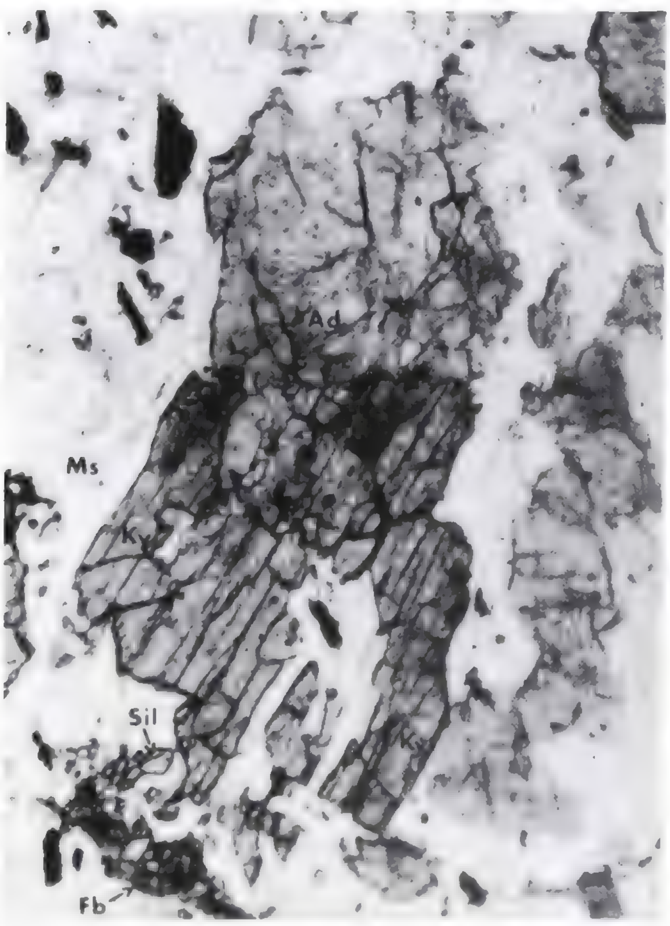


Fig. 3.

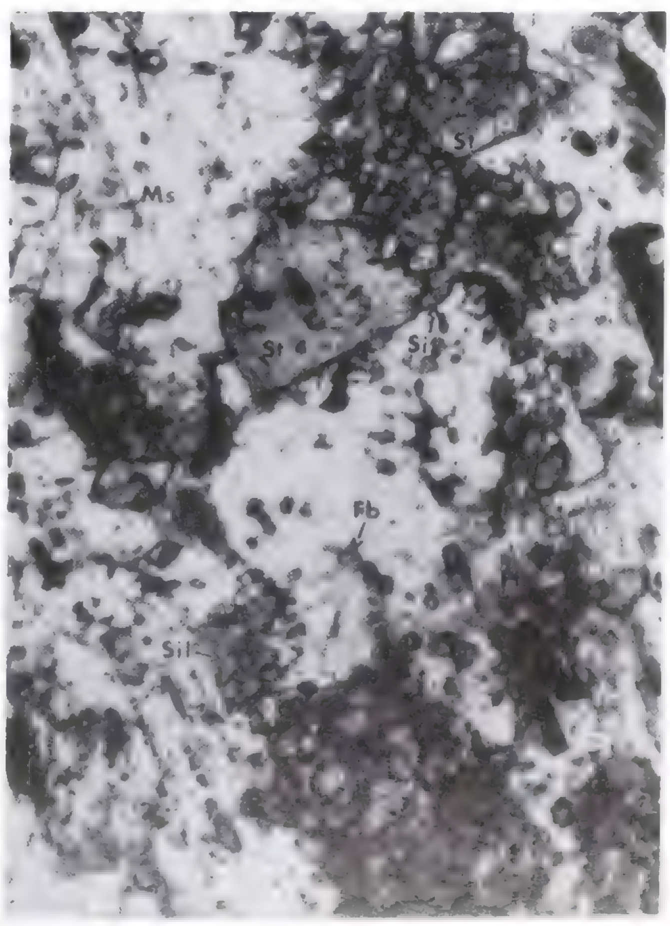


Fig. 4.

IV. SHORT ACCOUNT ON THE GEOLOGY OF THE UPPER WARDUJ VALLEY AND ZEBAK SURROUNDINGS

1. INTRODUCTION.

No mention has been made, in our earlier regional geological reports, of the upper Warduj valley and of the Zebak surroundings because these localities were only cursorily investigated by A. DESIO between the 25th and the 27th of August, 1961. Furthermore the geology of those areas is not very known at present and it is, therefore, useful to give a brief description here (1).

The samples collected by DESIO were studied by G. PASQUARÉ and by F. FORCELLA; the granite which outcrops in the surroundings of Zebak was dated by the Rb/Sr method at the Institute of Nuclear Geology of the University of Pisa (see page 214).

About the previous knowledge, one of the first who summarily wrote on the geology of the upper Warduj valley and Zebak area was K. BRÜCKL (1935). According to this author, along the whole Warduj valley hornblende gneiss with numerous layers and lenses of limestone crops out. From the surroundings of Zebak BRÜCKL noticed the presence of a conglomerate deposit which he attributed to the « Red Grit Series » of Cretaceous age (1). Between Zebak and Ishkashim the conglomerate seams to be crossed by a « light-green serpentine ». Eastward a large outcrop of Wakhan slates begins.

More recently, in the same area some new data were published by H. SAWATA (1962). His very short report deals with the Quaternary deposits, but it contains also some geological sketch-maps outlining the geological constitution of the region. Within the Warduj valley two formations are indicated: « granitic rocks and gneissose granite » from the outlet of the val-

(1) The Pleistocene deposits are discussed in another chapter (page 339).

ley upstream as far as Chakaran; more upstream « banded gneiss » as far as Bashum. From this site upstream the map shows « slate; schistose hornfels » for about 6 km, and than banded gneiss as far as Zebak. Near Tergeran a granitic rock crops out.

2. UPPER WARDUJ VALLEY.

As shown in the geological map enclosed with the present volume, the mouth of the valley, near Baharak, is marked by the faulted contact in the granite gneiss which, to the east of Dashtek, passes into augen gneiss. The granite gneiss towards the Baharak basin tectonically overlies the Furmoragh black slates; the slates dip beneath the granite at an angle of 45°-50°. The tectonic contact in sub-parallel to the schistosity.

Another fault of minor importance has a very steep fault-plane and, further to the west, cuts the Furmoragh black slates; its presence is shown by the difference in inclination of the schistosity planes on either side of the fault (Fig. 34).

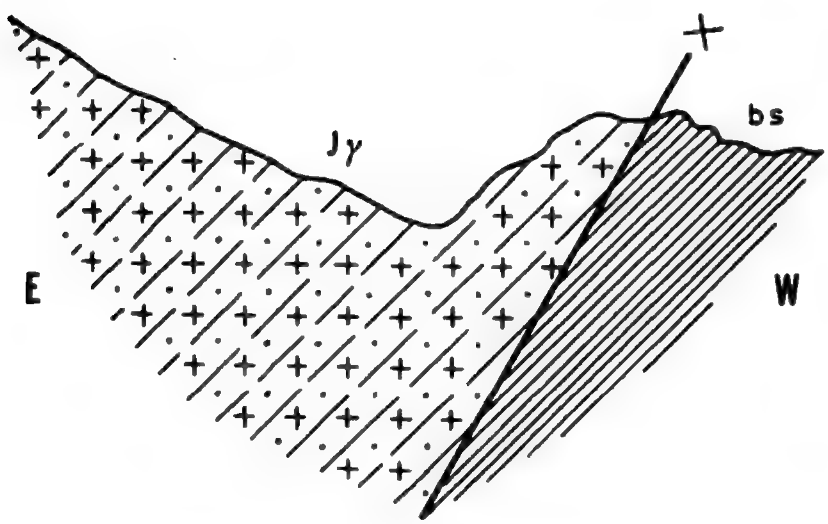


Fig. 34 - Geological section across the spur on the left-hand side of the outlet of the Zardew valley in the Baharak basin. (Jγ - sialic gneiss granite; bs - black slate). (From Desio's field book).

Towards the east the granite-gneiss is in contact with one of the southern apophyses of the granodiorite pluton forming the rigth hand slope of the lower Zardew valley (Baharak Granodiorite).

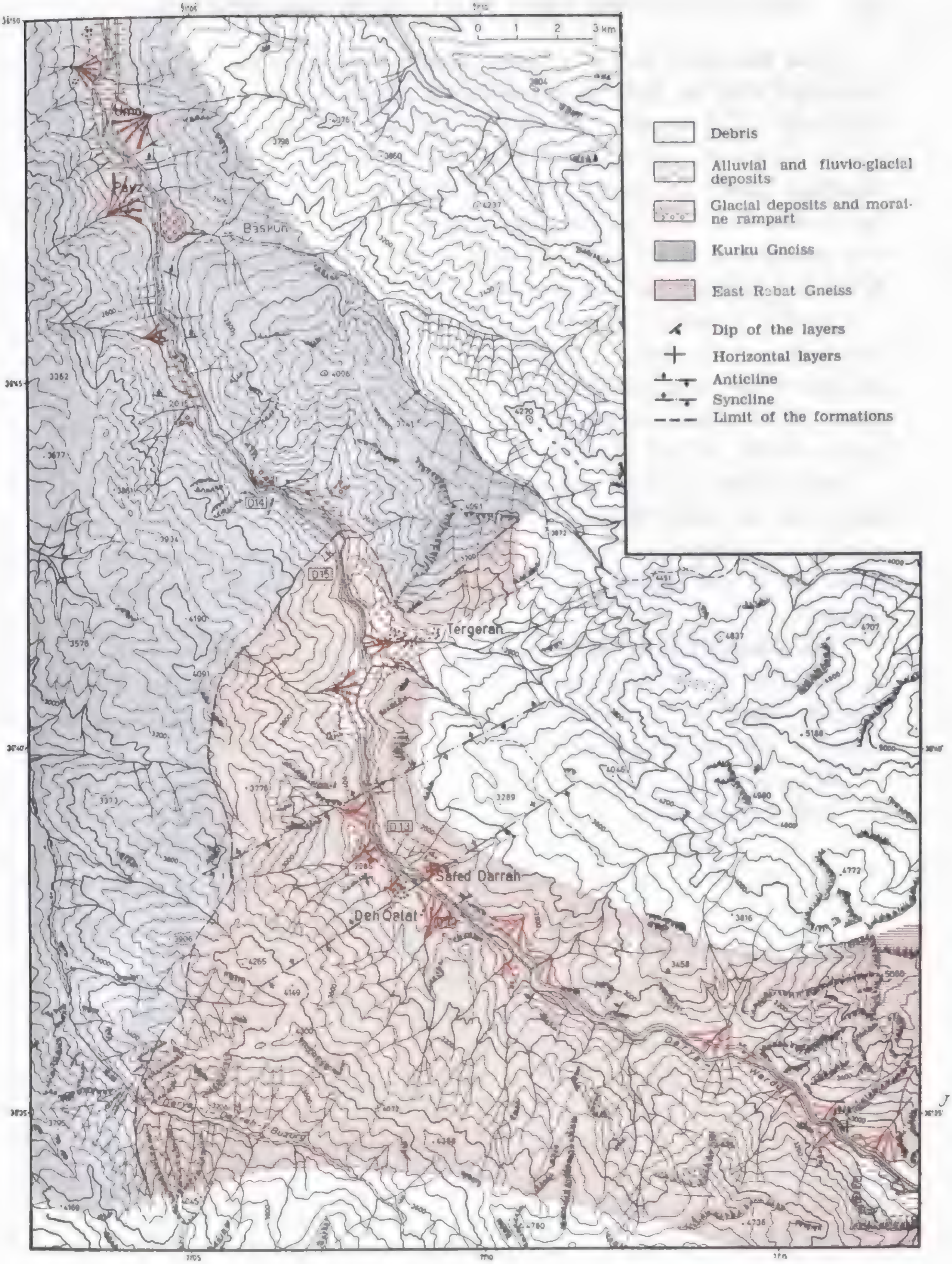


Fig. 35 - The upper Warduj valley and his geological feature.

Near the Ardar bridge a quartz diorite body crops out and possibly is connected with the Baharak granodioritic pluton which is exposed toward north-east. The samples collected in the above locality are made up of quartz diorite (61 AD-9/1) and quartzitic microdiorite (61 AD-9/2) with abundant biotite among the femics. In the vicinity of the bridge is visible the contact belt between the plutonic body and a parametamorphic formation represented in our collection by samples of biotite-garnet quartzite (61 AD-2) and biotite-garnet hornfels (61 AD-2/2).

Further upstream, in the lower Warduj valley, between Serak and Ushkan, the Baharak Granodiorite passes into the migmatitic gneiss complex which was named Tarang Gneiss (page 182). Immediately upstream from Ushkan, on the right-side of the valley, a small outcrop of *leucogranodiorite* (61 AD-7) is esposed.

Still further upstream *gneissose granodiorite* is present with layers dipping about 50° to the W and WNW, and occasionally the rock contains large crystals of feldspar; a short distance further downstream, however, the layers dip in the opposite direction, that is towards the SE, outlining one anticline.

The Tarang Gneiss outcrops on both slopes of the Warduj valley up to Chakaran, where they represent the transition into the migmatitic gneiss complex which was named *Kurkhu Gneiss* (page 178); they also form an extensive outcrop toward north, in the lower Zardew valley.

Between Chakaran and Tergeran (Fig. 35) the *augen gneiss* is prevalent and contains large crystals of feldspar (augen gneiss); it shows distinct layers which mostly dip to the north with a moderate or low angle.

Immediately upstream from Aqshira, on the right-side of the river, a large lense-shaped body of *leucogranodiorite* (61 AD-13/1) included in the fine-grained paragneiss (61 AD-13) outcrops, a sample of which was collected and an age determination was carried out using the Rb/Sr method. The sample was found to be 14 M.Y. old and can, therefore, be assigned to Miocene (Desio, Ferrara & Tongiorgi, 1964).

Another lense-shaped body of the same rock-type is also present about 4 km downstream from Tergeran (61 AD-14). These intrusions appear to belong to the sialic gneiss-granite belt of Baharak outcropping toward north and their lithological characteristics and age are similar. About three and half kilometres downstream from Tergeran, the Kurkhu Gneiss disappears

and is replaced by a gneissic formation (*East Rabat Gneiss*) characterised by intercalations of white *marble* associated with *epidote schist* and *biotite amphibolite* (61 AD-15). At this location the layers dip 45° to the north-west, but further upstream, near Deh Qalat, they plunge in the opposite direction (SE) and define an anticlinal structure the axis of which corresponds to the river-course.

Further upstream, near Kazdeh village, the dip of the layers is again reversed and defines a synclinal structure. Still further upstream a NW and WNW dip is predominant again.

A complex which is lithologically very varied and very different from the previous one outcrops immediately upstream from Deh Qalat. It consists of quartzite, amphibolite and migmatitic gneiss (61 AD-16/1) injected by quartz diorite (61 AD-16). The Rb/Sr method was used for age-dating this rock which gave a value of 29 M.Y., that is Oligocene age (DESIO, FERRARA & TONGIORGI, 1964).

Between Kabek and Rabat-i-Cheheltan, on the right side of the valley, the white marble outcrops again together with the rocks mentioned previously; they are part of the gneissic complex and are crossed by pegmatite veins. The same complex, which can be correlated with that known as *East Rabat Gneiss* (page 165), extends through the entire upper Warduj valley up to a point near Zebak. The boundary between the Kurkhu Gneiss and the East Rabat Gneiss is gradational. The dip of the layers becomes gradually less steep in this direction, whilst near Rabat-i-Cheheltan and still further to the east they become almost horizontal.

The East Rabat Gneiss which outcrops in the upper Warduj valley represent the southern continuation of the Koh-i-Khus Darrah outcrop, which is also shown in the geological map enclosed with the present volume.

3. THE ENVIRONS OF ZEBAK.

The village of Zebak is situated on the alluvial fan of the Darrah-i-Yasek, a right tributary of the main valley (Darya-i-Sanglich) descending from the Hindu Kush range. Immediately downstream from the village the valley divides into two branches, one of which swings towards the west (the

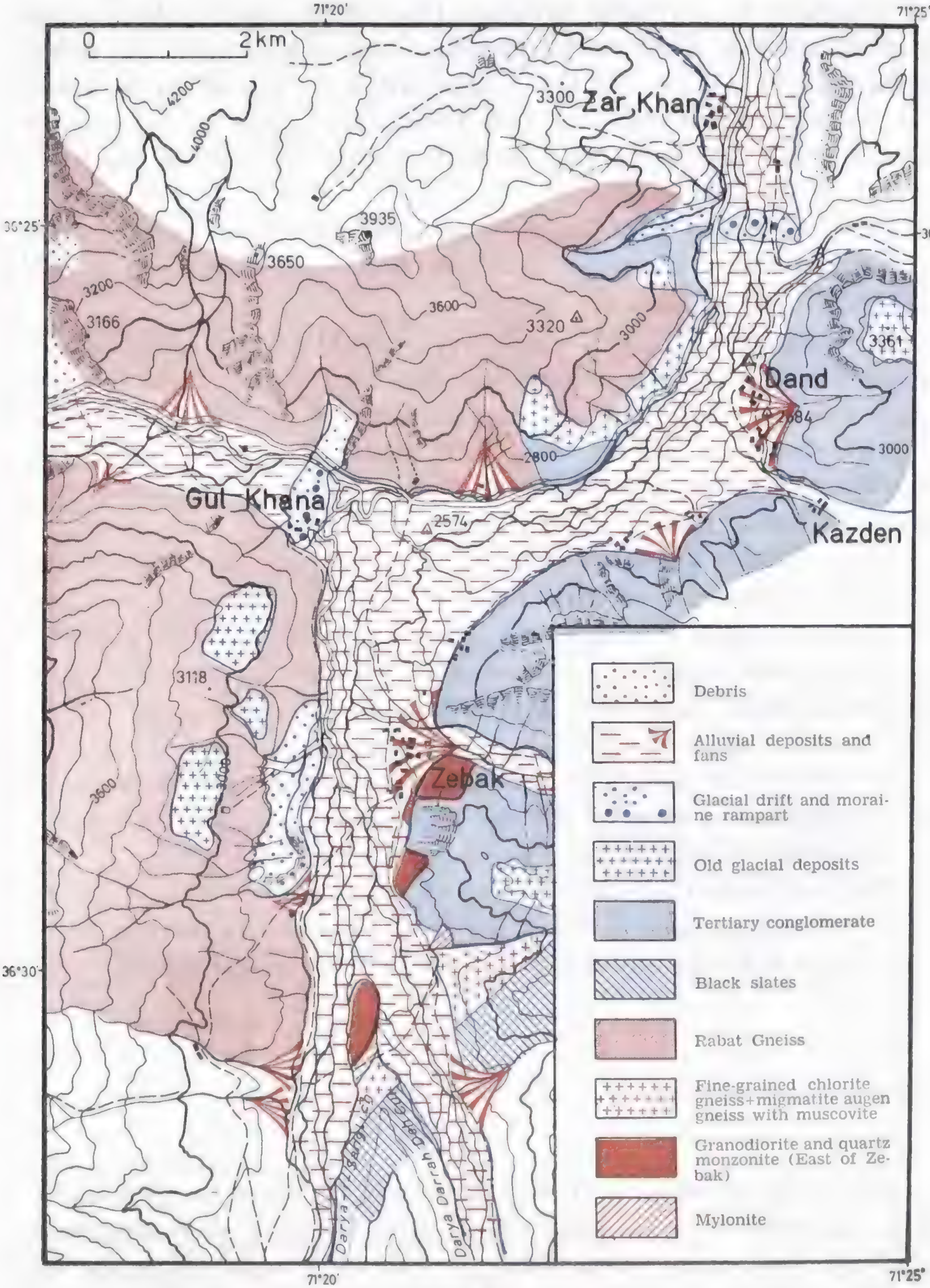


Fig. 36 - Geological sketch-map of the Zebak area.

Warduj branch which descends towards the Kokcha), and the other extends generally towards the north-east, that is towards Ishkashim and the course of the Ab-i-Panj. Hydrographycally, however, this second branch remains partly a tributary of the Warduj river (and represents its upper course), and partl a tributary of the Ab-i-Panj, as already mentioned.

The geomorphological phenomena which caused this unique feature will be described in a following paragraph (page 366) and therefore only the geological outline of this area will be shorty described here according

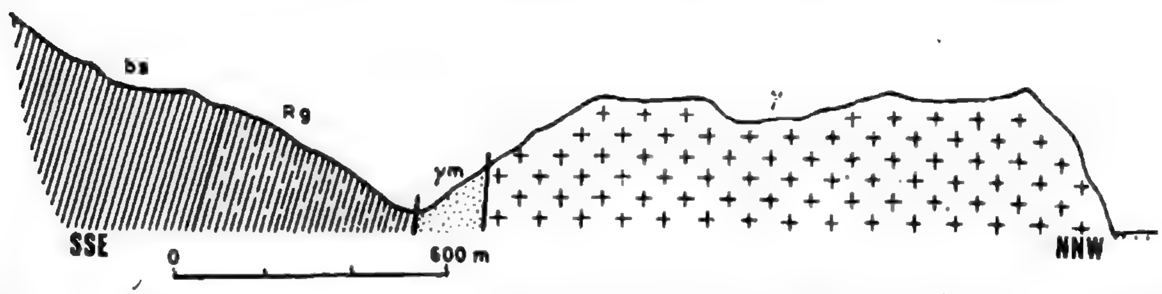


Fig. 37 - Geological section across the spur at the junction of the Deh Gol with the Sanglich valley. γ - granodiori, γm - granitic mylonite, Rg - Eastern Rabat Gneiss, bs - black slates, (From Desio's field book).

to the information collected during the rapid investigation carried out by a member of the 1961 expedition (Desio).

The Rabat Gneiss, outcropping in the upper Warduj valley, compose all the mountains which rise to the west and north of the Zebak valley and disappears at a fault line (Fig. 36). This dislocation, called Munjan-Zebak Fault (Desio, 1965b), follows the course of the Sanglich river for a distance and then cuts through the spur at the confluence between this valley and the Deh Gal valley. Then it continues, intersecting the slopes overlooking Zebak and moving towards Ishkashim where it joins the South Pamir Fault, the western continuation of which it represents.

The fault is well exposed in the spur at the confluence mentioned above and on the eastern slope of the main valley, immediately upstream from Zebak. This spur is formed by a long « promontory » cut by a furrow (Fig. 37, Plate VIII, fig. 1) eroded in a white, powdery and very friable granodioritic mylonite (61 AD-18), almost 200 m thick. The fault-plane is almost vertical and its orientation varies between N-S and NNE-SSW. To the north-

west of the fault a partly mylonitized white quartz monzonite (61 AD-19) is exposed which forms the terminal part of the confluence spur and three small outcrops on the eastern slope of the principal valley upstream from Zebak (Plate VIII, fig. 2). On the opposite side of the fault there is a greenish fine-grained chlorite gneiss, migmatite and gneissic granite (61 AD-18) which is almost totally mylonitized. In the opposite direction, it is contact with black slates forming the reliefs located to the SE. The total thickness of the mylonites, and of the rocks which are partly or almost completely mylonitized, is more than 1000 m. The black slates can be correlated with the Khandut Slates of Wakhan (see page 301).

Apart from the three outcrops of white granodiorite, the valley slope around the village is made of a conglomerate with arenaceous intercalations. The conglomerate is mostly formed of medium-sized pebbles of granite and granodiorite associated with black slates and various types of gneiss. The matrix is mostly arenaceous, and yellow and reddish in colour. The bedding is irregular but generally they plonge with an inclination of 30°-40° toward east. The beds are also weakly folded.

This conglomerate, called *Zebak Conglomerate* in order to distinguish it from other similar formations, discordantly overlies the white granodiorite and the East Rabat Gneiss and forms the reliefs overlooking the Zebak village and those flanking the principal valley towards Ishkashim. On the eastern side, the formation underlying the conglomerate outcrops only in the neighbourhood of Khaspak where P. Guj observed a strip of grey, coarse-grained sandstone, unconformably overlain by the conglomerate whose stratigraphic position is unknown; nothing is therefore known about its age. The same sandstone was observed by Mirwald & Roemer (1967) below the village Surkh Darrah, between Ishkhashim and Zebak, but the authors do not supply with any detailed data. On the opposite side, where the conglomerate is absent, the East Rabat Gneiss outcrops extensively towards the north and north-east, and forms the mountain ranges of the Koh-i-Kamir and Koh-i-Gharib.

The conglomerate is discordantly overlain by a bluish, muddy formation occasionally eroded to such a degree as to suggest a similarity with the oldest « skeletal moraines » of Karakorum (see page 364).

Some comments on the geology of the area around Zebak will now be made. No further comments will be made regarding the East Rabat Gneiss

the outcrop of which, in the area toward west, have already been mentioned (page 285).

Two samples of white quartz monzonite (61 AD-19/a and b) collected in the neighbourhood of Zebak were dated with the Rb/Sr method [1]. The first sample gave a result of 86 M.Y., the second 93 M.Y. These rocks, therefore, have an Upper Cretaceous age and can perhaps be correlated with the Babatangi and Lungko Granodiorite of the Hindu Kush (Desio, Guj & Pasquaré, 1968).

Regarding the age of the black slates, and assuming that those outcropping around Zebak can be correlated with the Khandut Slates which in the Wakhan region were intruded by the Babatangi Granodiorite, it can be stated that they are older than the granodiorite. On the other hand the Babatangi Granodiorite is similar to the granodiorite outcropping around Zebak which, as already mentioned, is Upper Cretaceous and therefore the Khandut Slates must be still older. This discussion will be continued in another paragraph (page 301).

The age of the Zebak Conglomerate must, however, be mentioned here. Of the formations overlain by the conglomerate the only one which has been dated is the Upper Cretaceous granodiorite outcropping in the neighbourhood of Zebak. This means that the deposition of the conglomerate, which, as revealed by its structure, irregular bedding and colour, is a continental formation, must have occurred during the Tertiary.

Among the formations which stratigraphically and structurally most closely resemble it, the Reshum Conglomerate, outcropping on the opposite slope of the Hindu Kush range, must be considered. This conglomerate, on the basis of other evidence (Desio, 1966), has also been assigned to the Tertiary.

In the Pamir there are several conglomeratic formations: one of them in particular is similar to the Zebak Conglomerate; that is the « Kurteka Formation » of the Southern Pamir, consisting of reddish-brown conglomerate 200 m thick. Its age ranges from Upper Miocene to Pliocene. Further up in the sequence, however, there are other conglomeratic-arenaceous formations and therefore a correlation based on our data appears doubtful.

The opinion of Archipov, Leonov & Nikonov (1970) regarding this

(1) The same samples were mentioned as granodiorite in Desio, Tongiorgi & Ferrara, 1964.

problem must be reported here. They suggest that « the red conglomerate some hundred of meters thick » outcropping in the neighbourhood of Zebak should be assigned « to the Lower Cretaceous or perhaps to the Oligocene-Miocene ». According to the author and to the above discussion, only the second of the two datings could be valid. This is apparently confirmed by statements of the same authors in another part of the same paper: « the lower red conglomerates, lying in erosion basins, are older (than Pliocene), mainly of Miocene age ».

The above mentioned authors add further that « near Zebak village, a grey conglomeratic formation generally about 500 m thick, overlies the red conglomerates, the Triassic-Jurassic schists and the granites of the belt extending for some kilometres from south-west to north-east ».

This formation consists of three members; a lower one of alluvial-fluvioglacial origin, a middle one of glacial origin and an upper one similar to the first. The three authors assign the upper member to the Lower Pleistocene, the lower and the middle members, most probably, to the Pliocene.

The glacial and fluvioglacial formations appear to correspond to that which has been considered similar to the « skeletal moraine ». This problem will be discussed again in the chapter dealing with the Pleistocene.

V. NOTES ON THE GEOLOGY OF SOUTHERN WAKHAN

1. INTRODUCTION.

1.1. Geographical Position.

Wakhan is that long narrow appendix to the north-east of the Afghan territory which runs like a corridor east-northeast, practically separating North-west Pakistan (to the south) from the Russian territory of Pamir (to the north) and from China (to the east). Wakhan is not a natural region, but a political district, although a relevant part of that territory is represented by a branch of the upper valley of the Amu Darya (Oxus river) which is known as the Ab-i-Panj [1] as far as Ishkhashim, as the Ab-i-Wakhan and further on as the Little Pamir.

Towards the south the borders of Wakhan run along the high crest of the Hindu Kush range, in many places more than 6000 m a.s.l. culminating with the Noshaq Peak at a height of 7492 m. Towards the north the Pamir river (Little Pamir), joins the Wakhan river near Qala Panja, and marks the border of Wakhan.

In this section we will deal only with the southern slope of Wakhan, that is with the northern slope of Hindu Kush.

1.2. Previous Research.

The geological literature relative to Wakhan up to now is rather scarce.

The first news was given by F. Stoliczka (W. T. Blanford, 1878) who came from the east and descended the valley of the Little Pamir and then

(1) *Ab* means water, and by extention also river.

that of the Ab-i-Wakhan as far as the confluence with the valley of the Pamir river which he followed until the source, afterwards proceeding east. STOLICZKA visited the greater part of Wakhan along the major valleys, but the geological news which has remained to us consists of notes on the journey and samples arranged for printing by BLANFORD. According to a summary relative to Wakhan by this author (p. 48) « The geology throughout is of the very simplest description. The carboniferous and triasic limestones were only found for a very short distance west of the Yarkand frontier; and thence to Janjah the whole country consisted of black slates, occasionally capped by reddish slates and conglomerates and resting upon gneiss, which forms the great mass of the plateau. The slates are doubtless paleozoic, but no evidence of their precise age was obtained. The gneiss is fine-grained; it contains biotite, and is in places traversed by veins of albite granite, and it altogether so much resembles the « central gneiss » of the Himalayas north of Simla, that it may be a continuation of the same rock. Immense accumulations of boulders and sand were observed on the Pamir, in all the river valley and around the lakes ».

Many years later H. H. HAYDEN (1916) arrived in south Wakhan for the first time when he reached the Baroghil and Shawitakh passes which cross the Hindu Kush range, afterwards returning to Chitral trough the Darkot pass. However he returned again to Wakhan from the east and explored principally the Wakhan range (Nicholas II range) which rises between the Pamir river and Ab-i-Wakhan, and he followed STOLICZKA's route to a certain extent. The precious memoir of HAYDEN is accompanied by a geological sketch-map which deals with the eastern portion of Wakhan, to the east of 73° 30′ Long. excluding the northern slopes of the Hindu Kush.

The greater part of the territory represented on the map appears to be made up of the so-called « Sarikol Shales and Wakhan Slate » with a zone constituted by « Granite and Metamorphic », corresponding to the Wakhan range. It is important to remember that, according to HAYDEN, the general character of the Wakhan Slates suggest that they are merely the metamorphosed representatives of the Sakirol Shales which, like the slates, underlie the « Pamir limestone ».

The Wakhan Slates seem to be represented by a series of slates and quartzite full of igneous rocks which sometimes appear to be intebedded and sometimes to be intrusive in the slates.

These same slates should also make up the southern slope of the middle valley of the Wakhan river under the Shawitakh pass, and according to HAYDEN, should be attributed to the Upper Paleozoic. In fact they should represent a homotaxial formation, a facies of shallow water, of the *Fusulina* limestone of Chitral.

Also K. BRÜCKL (1935) left us some information about the western part of Wakhan, as far as Pegish, which the two preceding authors had not visited. All that stretch of the valley, at least in the part of the river which is visible, should be composed of black slate with concordant intercalations of gneiss, dipping 30° south-eastward.

The black slate, attributed by the author to the Wakhan Slates mentioned by HAYDEN, are crossed by granite intrusion in the form of laccolites, which send apophyses into the black slates. Near Urguni (Urgand) a granite body crops out with magnificent orthoclase crystals and with pegmatites.

The Russian scholars have produced far more abundant literature, which refers essentially to the territory situated to the north side of the Amu Darya, and particularly to that vast tectonic zone, namely South-West Pamir. We cannot dwell however on this area and its numerous geological problems.

We remember only that the bases of the geological knowledge of that zone was laid by the geological expedition to the Pamir directed by D. V. NALIVKIN in 1932. The data collected were elaborated (for the area concerning us) specially by S. I. KLUNNIKOV (1936). Numerous other authors contributed in reviewing and perfecting the interpretations of that time.

In 1960 a Japanese expedition visited one part of Wakhan with alpinistic purposes. Two years later M. SAWATA published a report dealing summarily with the geology of Wakhan, mostly with the Pleistocene deposits from Ishkhashim to the confluence of the Qaz Deh valley. The geological knowledges are prevailingly contained within some small sketch-maps. The geological formations recorded by SAWATA in Wakhan are substantially the following: « banded gneiss, slates, limestone, hornfels, granitic rocks and gneissose granite » with dykes of pegmatite and aplite.

An other report on the Wakhan by P. MIRWAL & ROEMER appeared in 1967. About the stratigraphy the two authors record the following units: a) sandy argillaceous schists passing into phyllite and locally also to chiasto-

litic « Knotenschiefer » and containing thick intercalations of quartzite and small lenses of calcschists and marble; b) granitic intrusiva belonging to two sequences one made up of gneiss-granite, the other of intrusive granite; c) basalt and granite porphyry; e) sandstone with fossil plants; f) red conglomerate.

About tectonics the authors speaks of two tectonic phases, with different orientation of the folding and faulting, one (older) Palaeozoic, the other Alpine.

About the Pleistocene and Holocene deposits, they will be dealed with a further section.

In 1963 P. GUJ undertook a journey in Wakhan ascending the valley as far as Rorung and carried out a reconnaissance in the Hindu Kush slopes.

The samples collected by him were studied by G. PASQUARÉ in the Institute of Geology, University of Milan (Italy) where also the field notes were elaborated under the leadership of the director professor A. DESIO. A report containing the results of these researches was published in 1968 by DESIO, GUJ & PASQUARÉ.

We reproduce here our report with some improvements in order to complete, as far as possible, our knowledge to the east of the area more attentively investigated by 1961 DESIO's expedition.

1.3. Outline of Geomorphology.

The upper valley of the Amu Darya between Ishkhashim and the eastern border of Wakhan is emplaced on an important fault line which at Qala Panj, where the Pamir river joins the Wakhan river, divides into two branches, of which one, perhaps the main one, follows the first of the two valleys, the other, the second one, and farther uphill the Little Pamir valley. It is not yet known if this last fault joins that of the Upper Hunza (DESIO, 1965b).

The upper valley of Amu Darya, as far as Qala Panj, is profoundly sunken between high mountainous chains which dominate it on both sides with summits above 6000 m and also 7000 m, the Hindu Kush range on the south, the Wakhan range on the north. Very different is the extension of the glaciers; the northern slope of the valley is covered by a thick mantle of ice, of which many tongues stretch out to the bottom of the secondary val-

leys which furrow the northern slopes of the Hindu Kush. On the opposite slope there are only secondary glaciers (cirque and slope glaciers).

Further upstream the valley shows a dissymmetric feature, the southern slope being steeper than the opposite one, while upstream from Bozai Gumbaz, where the valley, which for chilometres had maintained an east-west direction, turns towords the north-east and the river assumes the name of Little Pamir. In the upper part of the valley, as far as the frontier of the territory of the U.R.S.S., this morphological feature is reversed and the right-hand slope becomes more inclined than the left. Just beyond the frontier the valley bends sharply to north-northwest while the river assumes the name of Ak-Su.

The valley of Pamir, upstream from Qala Panj, is bounded on the north side by the Alichur chain and on the south side by the Wakhan chain.

This disparity of inclination of the sides of the valley largely depends on the attitude of the strata. Where these dip in reversal direction of the slope is steeper.

Both the principal valley of the Ab-i-Panj and its tributaries bear the imprint of the moulding of the glaciers which descended from the high ridges of the Hindu Kush during the Quaternary expansions, and — although to a lesser degree owing to the southern aspect — also from those of the Wakhan range, and buried the valleys up to a notable height. The major extension of the glaciers on the southern slope is now testified by the large mass of glacial and fluvio-glacial deposits, as well as the exceptional development of the alluvial fans which are lacking on the opposite side of the river.

The large glacier of the Amu Darya probably continued down to Ishkhashim but we do not know where it ended. However it seems that one iceflow re-ascended the valley of Zebak were Desio noted extensive glacial deposits of different ages (page 364), some of the highest could have been deposited by this lobe. Also the lower valley of Arakht, below Shiwa lake, was probably occupied in its lower part by a lobe of the Amu Darya glacier.

Now we must remember that if the geolithologic composition does not seem to have exercised a determining influence in the landscape but only in morphological details, a substantial imprint has been left by the tectonics.

As we have already mentioned, the upper valley of the Amu Darya and

its main tributaries, the Pamir river and the Wakhan river, are emplaced in a important fault lines which separate two different orotectonic systems (Desio, 1965b).

After our investigations, which are limited to the valley of the Amu Darya up to the height of Rorunq, a system of fractures and reverse faults was observed in direction N 50°-55° E, intersected by a second system approximately orthogonal on which is emplaced the river system of the north slope of the Hindu Kush.

The second system is composed of normal faults with N 25°-30° W direction, with variable dip but prevalently south-west. This system gives to the right flank of the valley the character of a block-faulted area from which are derived the assymmetric valleys of Palup, Yama, Varang, etc.

This morphologic character, evident on the right flank, has been cancelled on the opposite slope by the strong glacier erosion caused by the Quaternary glaciers which were much more developed on that slope of the Hindu Kush, as already mentioned.

2. STRATIGRAPHY.

2.1. Introduction.

From the stratigraphic point of view the constitution of Wakhan depends on the concordant trend of the valley of Ab-i-Panj with the tectonic attitude of the stratigraphic units (Fig. 38). These units can be defined in the following succession, from the most ancient to the more recent:

1) Qala Panja Quartz Diorite: mass of plutonic rocks prevalently of quartz dioritic type, strongly cataclastic and dynamometamorphic;

2) Qala Wust Gneiss: complex of gneissic rocks of different composition and origin constituting the envelopment of the quartz dioritic mass of Qala Panj;

3) Khandut Slates: complex of dark schistose parametamorphic rocks;

4) Babatangi and Lungko Granodiorite: axial batholith of the Hindu Kush of essentiall granodioritic composition with collateral facies and late differentiations from granite to diorite.

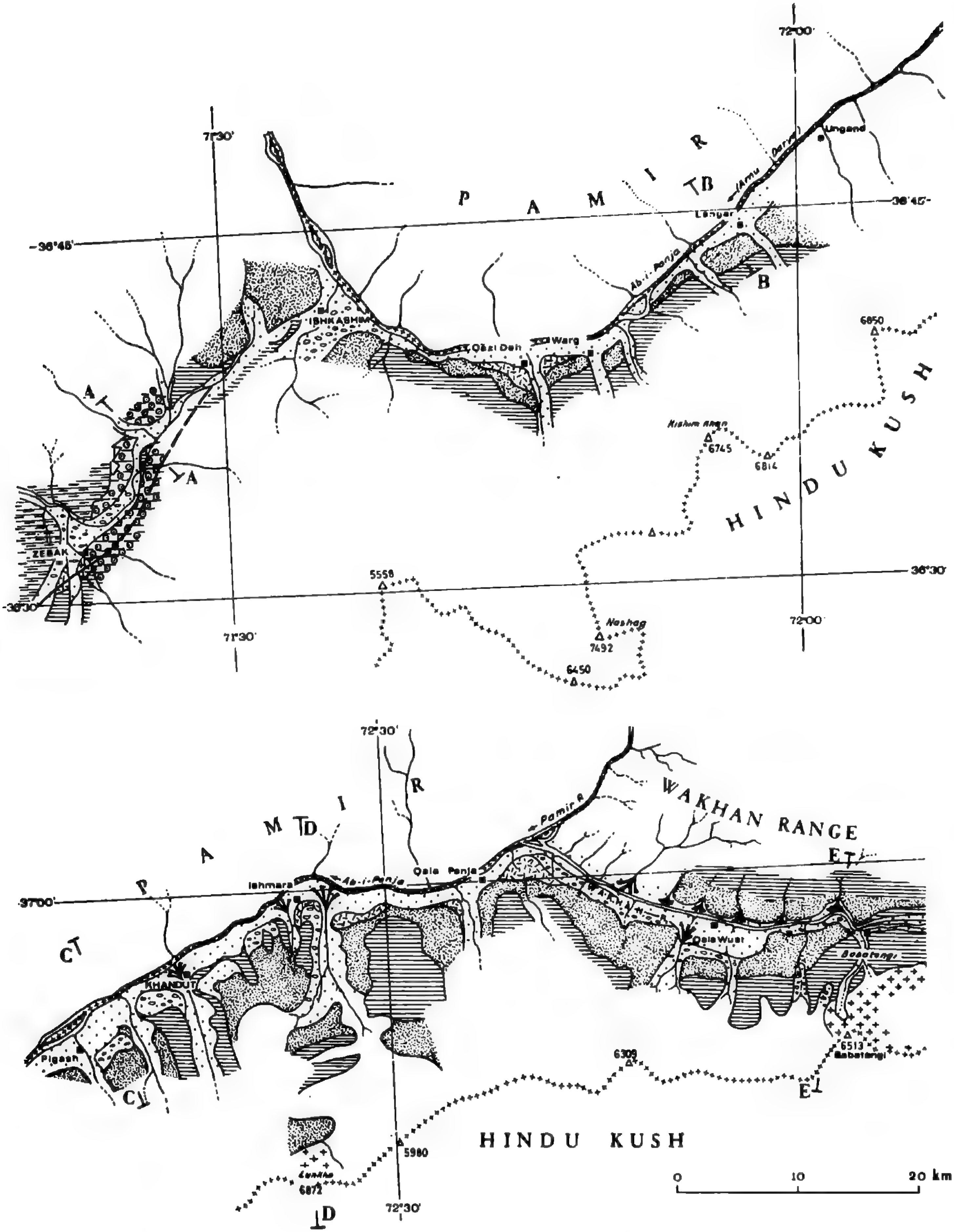


Fig. 38 - Geological sketch-map of the southwern Wakhan by P. GUJ, 1963. (Legenda in fig. 39).

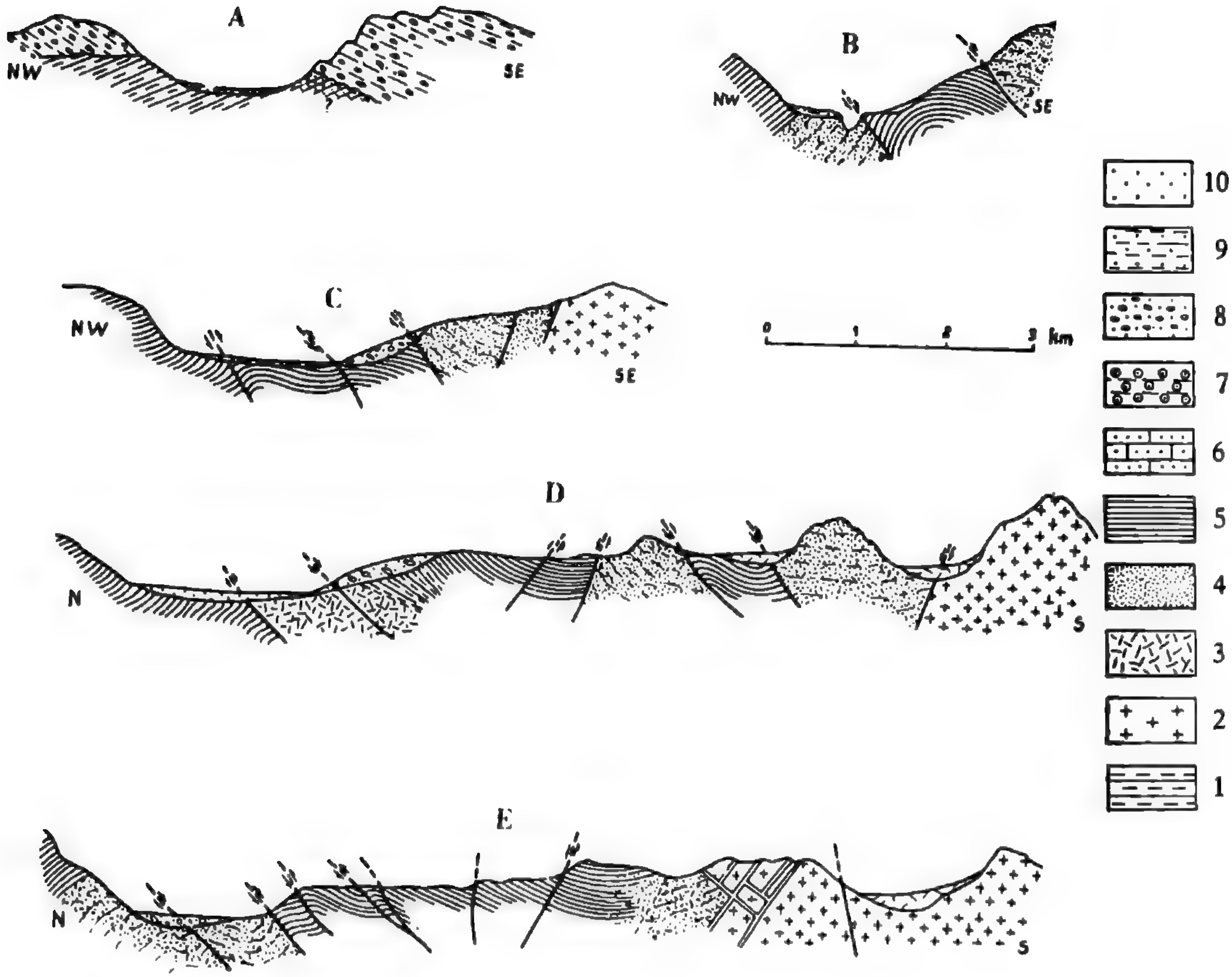


Fig. 39 - Geological sections across the southern Wakhan by P. GUJ, 1963.

1 - East Rabat Gneiss, 2 - Babatangi (& Lungho) Granite, 3 - Qala Panja Quartz Diorite, 4 - Qala Wust Gneiss, 5 - Khandut Slates, 6 - Grey coarse sandstone, 7 - Conglomerate & sandstone (Tertiary), 8 - Glacial deposits, 9 - Fluvial & fluvio-glacial deposits, 10 - Debris.

The four units seem to be quite regularly overlain from the bottom of the valley towards the crest of the Hindu Kush, in an order of succession locally disturbed by transversal tectonic accidents and by wide folding of the metamorphic rocks. Owing to the lack of fossils their age in unknown, but it is possible to make some suppositions through comparison with formations of the surrounding areas as we will see later.

We have to remember here other three lithostratigraphic units, because they are marked on the sketch-map fig. 38 [1]. These units are not present

(1) The geological sketch-map was surveyed by GUJ except the area of Zebak which was surveyed by DESIO in 1961.

in Wakhan, but just to the western limit, within the valley between Ishkashim and Zebak.

To the north and west of the last village the Rabat Gneiss outcrops. This formations is generally composed of fine-grained gneiss, very rich in biotite and characterized by a schistose, banded, or porphyroblastic-banded structure. At the base it is garnetiferous. Banded white and grey marble is frequently and repeatedly interbedded. It grades into calcphyre along the contact with the gneissic rocks (page 287). DESIO, who visited the surrounding of Zebak, was not able to see the contact betwee nthe East Rabat Gneiss and the gneissis formations of Wakhan, therefore the relation between such formations remains unknown.

In the same valley, north-east of Zebak, there are extensive deposits of red and yellow conglomerate and coarse-grained, cross-bedded, unfossiliferous sandstone which provisorily have been attributed to Tertiary, as they overly with unconformity the other formations, exept the Quaternary deposits (glacial and fluvial).

Finally GUJ remarked one outcrop of grey coarse-grained sandstone, overlied with angular unconformity by Tertiary strata, near the outlet of a small valley north-est of Zebak. We lack details about this sandstone, though it may belong to a Cretaceous formation.

2.2. Qala Panja Quartz Diorite.

At the base of the Qala Wust Gneiss, and in two different localites at the bottom of the Ab-i-Panj valley, near Qazi Deh and near Qala Panja, massive intrusive equigranular rocks crop out, rich in mafic elements with traces of dynamometamorphism (sample 63 GE-11). Their quartz dioritic composition is often partly cancelled by the successive mechanical deformation accompanied by metamorphic transformation of epizonal character. Unfortunately the contacts between this quartz diorite and the overlying metamorphites of the Qala Wust formation are hidden by a thick deposits of glacial material and debris for which it is not possible to determine the reciprocal stratigraphic position of the two adjoining formations.

2.3. Qala Wust Gneiss.

The Qala Wust formation enclose the lithotypes of distinctly gneissic character cropping out over vast extensions on the bottom of the Ab-i-Wakhan valley between Ishkashim, Khandut, Qala Wust and Rorunq. Between Ishmara and Qala Panja these constitute the envelopment of the dioritic mass of Qala Panja, cropping out again in an anologous position further to the west, around Qala Deh. On the upper levels the formation itself generally grade into the Khandut Black Slates. In spite of this constant stratigraphic position as well as a good lithologic homogeneity throughout all the outcrops, the Qala Wust Gneiss genetically is made up of very different lithotypes. Under the common gneissic aspect are in fact hidden typically sedimentogenic gneiss, other of clearly granitoid derivation, as well as dykes and sills of aplitic composition.

The stratigraphically deepest types were found along the right hand slope of Abi-i-Panj, upstream from Qala Panja (63 GE-1, -2, -3, -4, -6, -8, -10) and consist of very feldspathic rocks with augen texture, generally with porphyroblasts both plagioclasic and K-feldspathic.

The micas appear in two clearly distinct generation: biotite and muscovite associated in microfibrous beds with iron oxide alterations, and often mixed with chlorite; porphyroblastic muscovite in very large, well preserved flakes lying indipendently in respect to the schistose fabric of the rock.

Between the feldspar porphyroblasts and the micaceous beds quartz feldspathic fine-grained groundmass enclosing isolated biotite crystals can be generally recognised.

Therefore, on the whole, an accentuated structural homogeneity can be noted which could suggest a metasomatic process of feldspathization, followed by late cinematic migration of pneumatolytic elements, with neoformation of muscovite porphyroblasts.

However, extensive field observation to consolidate such a hypothesis are lacking. The connections with the underlying dioritic mass of Qala Panja,which would be of decisive importance in solving the problem, are still obscure.

With regard to the essential composition of the gneissic rock, with the exception of the porphyroblasts, generally an intimate mixing of ologoclasic

plagioclases and K-feldspar can be observed, sometimes lying with granoblastic structure, and sometimes micropegmatitic and aplitic aggregates.

To the west of Qala Wust repeated intercalations can be observed of fine-grained biotite paragneiss identical in structure and composotion to the paragneiss of the Khandut formation (63 GA-4, 63 GB-4).

2.4 Khandut Black Slates.

This formation consists of a thick sequence of slates and dark, almost black, arenaceous schists, sometimes of phyllitic character, often alternating with more or less thick beds of white or grey marble or quartzite. Further, the formation appears to be densely crossed by quartz-feldspar veins of varying importance, both concordant and discordant. In the midst of the formation itself, portions can be distinguished in which the primitive sedimentogeneous character is well preserved, and others in which the metamorphic action appears more accentuated. The first usually correspond to the pelitic or arenaceous types (63 GA-1, -8; 63 GD-2), the second to quartzitic or slaty types (63 GD-3, -5, -6, -8, -9). The entire metamorphism seems to be epizonal in character grading to mesozonal and is specially characterized by the co-existence of muscovite and biotite even in the lithotypes in which the sedimentary textures are still discernible today. The feldspar generally appear as granules of detritic origin in a few fine-grained biotite paragneiss. Phenomena of feldspar enrichment are only found near the contact with the granodiorite of Babatangi, which is described later.

The even rhythmic alternating of the above mentioned lithotypes can be differently explained throughout the area examined; in the eastern part of the valley there is progressive increase of the quartzite and slate levels, which stand out on the slopes in the form of relatively thick beds up to one metre in thickness, and lighter in colour than the average.

The Khandut Black Slates border all the southern slopes of the Ab-i-Wakhan valley with a varying width, until they disappear at the point where the micaschist-gneiss complex of Qala Wust interposes at the contact with the batholith of the Hindu Kush. Its thickness in the Ishmara valley is estimated at about 2500-3500 m, and in the Rorunq-Racau valley about 3000-4000 m.

The bedding is always evident and shows varying thickness from a few centimetres to 1-1,5 m, and always appears more accentuated owing to the marble and quartzite beds.

A system of lineations with east-west trend and a schistosity directed to N 70°-80° W with varying inclination and dip (but mostly towards the north) are almost constantly present.

The bedding surfaces sometimes show a series of globules or elongated molds which, on a reduced scale, remind one of a combination of *flute casts* and *load casts*. These molds are particularly frequent in the samples taken in the valley of Babatangi.

The direction of the strata is generally sub-parallel to the valley, tending to become east-west towards Qala Panja; the dip is mostly turned to the south-east or south with an inclination of 20°-40° along or near to the main valley, diminishing by degrees as one proceeds up the lateral valley.

The variation in the inclination generally happens gradually, while that of the dip seems to be in relation to an east-west fracture system which is principally developed in the midst of the gneiss near to the contact with the batholith. It is along this system of fractures and faults that the greater part of the sialic late magmatic apophysis and mafic differentiations are intruded. The relationships are shown in the cross section D (Ishmara valley, Triade and Lunkho peaks) and E (valley upstream of Babatangi). However, there are some spots, especially near the contact with the underlying gneiss and micaschists of Qala Wust, along the valley of the Ab-i-Wakhan and Ab-i-Panj, in which the formation appears so strongly contorted and tectonized that it suggest the existence of a repeated sequence of different overlying formations or part of them.

In the valley of Pakh and nearer to the village of Patur (Babatangi) a series of inverse faults overlaps numerous tectonic units of the Khandut black slates one on the other until they come into contact with the Qala Wust Gneiss. The direction of the fault planes is about N 50°-60° E with southern dip. The cross sections B (Shirkaf) and C (Yumtir) as well as the already mentioned D and E enable one to see the connection between the two formations. These tectonic relations do not exclude the fact that some members of the Qala Wust formation were originally in regular stratigraphic succession at the base of the Khandut black slates. In fact, in the area down in the Qala Panja valley it is difficult to establish an exact contact-line between

the two formations owing to the graduality of the passage which continues for a thickness of over 600 m. In this area are found essentially fine-grained paragneiss (63 GB-4), with some reappearances of dark arenaceous schists characteristic of the upper-middle part of the Khandut formation (63 GA-11). In this transition series it is possible to observe repeated intercalations of sills of an olocrystalline fine-grained rock with porphyritic texture of plagitrachitic composition (63 GA-6, -10) with thicknesses of up to 5 m.

The discovery of these rocks constitutes a motive of correlation with analogous rocks found more to the east. In fact, HAYDEN (1916, p. 301) reminds us that « in the Little Pamir the slates are penetrated everywhere by intrusions of dark, igneous rock » which he believes to be the same as that outcropping in the Karakokti and Karachukar (Taghdumbash Pamir).

According to H. WALKER, who studied the samples collected by HAYDEN, these rocks are to be regarded as dacite and as quartz andesite.

According to HAYDEN, pebbles from those rocks are also contained in the Tertiary conglomerate of Reshun, near Avi, and thus their age should be pre-Tertiary, but later than that of the slates which HAYDEN believed to be post-Palaeozoic.

It therefore seems very probable that the plagitrachite of the Qala Panja could represent the dacite and quartz andesite included in the black slates further to the east.

2.5. Babatangi-Lunkho Granodiorite.

The axial zone of the Hindu Kush range is occupied by a batholith of granitoid rocks stretched according to the orographic directions, that is from SSW to NNE (DESIO, 1960). The roof of the batholith, made up fundamentally of the metamorphites of the Khandut and Qala Wust formations, had been removed almost everywhere by the erosion along the axis of the range, where the granitic infra-structure is exposed in an imposing succession of peaks, the greater part of which reach heights varying from 6000 to 7000 m, and culminate in the 7392 m of Mount Noshaq. The axial batholith of the Hindu Kush was reached at two points in the course of the GUJ expedition

1963, in the Babatangi chain, at 6513 m, and in the Ishmara and Lunkho range, the latter with a height of 6870 m.

In the Babatangi chain the roof of the batholith is made up of black slates and fine-grained paragneiss of the Khandut formation and the contact is characterized by a vast belt of injections and of endomorphic contaminations of igneous rocks.

The contact zone was observed along the Babatangi valley at about 4000 m of altitude.

Facies of injection gneiss (63 GD-13), garnetiferous banded gneiss (63 GD-14) and feldspar augen gneiss (63 63 GD-4), are to see in the metamorphites next to the usual dark paraschistose facies (63 GD-7).

The emplacement of the Hindu Kush batholith have evidently superimposed mineral paragenesis of progressively deeper and deeper zones to the prevalently epimetamorphic series constituting the Wakhan. On the whole, two zones can be observed: « biotite and garnet zone » on the outside, and « biotite, garnet, orthoclase and plagioclase zone » on the inside, this last noteworthy for a typical migmatitic facies.

An intense late- and post-cinematic leaching of the alkali present in these rocks has led to the growth of muscovite porphyroblasts in the metamorphites themselves, even at great distance from the batholith.

A very coarse-grained rock, with slightly oriented structure, corresponding to a leucogranodiorite (63 GC-1) is found in direct contact with the schists. In the mass, which appears crossed by numerous aplite dykes (63 GC-3), diffused dark schistose arenaceous xenolites can be observed.

In the peripheric belt also appear granular masses slightly more femic of a distinctly porphyritic texture, quartz dioritic in composition (63 GD-16).

The relation between these masses and the leucogranodioritic types has not been made clear.

Little by little as one proceeds towards the axial zone the number and the dimension of the feldspar megacrystals diminish and the rock assumes a tipically equigranular structure, while the composition stabilizes itself as granodioritic type (63 GD-15, -17, -19). Further massive differentiations can be observed, probably contemporary with the emplacement of the granodioritic body whose composition varies between quartz diorite (63 GD-16) and calc-alkaline granite (63 GC-4). The principal mass seems to be crossed with numerous dykes which have been prevailingly intruded into a system

of vertical joints or slightly dipping to the north, in east-west direction. These late magmatic convoys are represented both by indifferentiated bodies, only distinguishable by a fine-grained fabric and by mafic microdioritic differentiations (63 GD-18).

The same dykes are to be found in a wide radius even in the sorrounding metamorphites. Also noticeable are lenticular masses of serpentinite (63 GM-18).

The mountainous range of Ishmara, on the other hand, seems to be fundamentally made up of augen gneiss and of garnetiferous biotite granite gneiss which, in the southern part, grade into quartz dioritic and granodioritic clearly porphyritic types, analogous to those forming the peripheric facies of Babatangi.

The essential difference from the latter consists in the fact that in the Ishmara the axial batholith remains in contact with the gneissic rocks of the Qala Wust formation. The contact probably takes place at a deeper level of regional metamorphism, thus facilitating the diffusion of mixed rocks of embrechitic and anatexitic types as are prevailingly the gneiss of the Ishmara range.

To recapitulate, it can be said that the granodiorite batholith appears to be enveloped along all the northern slope of the range by the above mentioned metamorphites.

Different petrographic and petrogenetic conditions occur at the contact of the granodiorite both with the Khandut and Qala Wust formations. The contact of the granodiorite body with the Khandut formation is noteworthy both for the endomorphic modification of the igneous mass and for phenomena of exometamorphism with mobilization and migration of elements into the paraschists themselves. The homogeneus petrographic composition of the batholith in its internal parts assumes in the peripheric zones a great variability both with sialic differentiation from leucogranodiorite to granite and with more decidedly femic, from quartz diorite to diorite. A network of aplitic microgranodioritic and microdioritic dykes and apophysis radiates into the metamorphites of the Khandut formations. The contact facies of the schists are noticeable by the diffusion of garnet and by an intense feldspathization which caused the metablastic growth of microcline and sodic plagioclase in the schists themselves. The contact with the Qala Wust formation, probably belonging to a deeper level, seems much more homoge-

nous and transitional, with large diffusion of mixed rocks of embrechitic and anatexitic type, grading to the granodiorite of the batholith. Actually one may also recognize in the axial batholith of the Hindu Kush that convergence of intrusive and thermo-metamorphic phenomena and of anatectic processes which were observed in the batholith of the Karakorum (DESIO & ZANETTIN 1957, ZANETTIN 1964) and in a few plutons of the Badakshan (DESIO, PASQUARÈ & SPADEA 1964).

3. COMPARISON WITH SIMILAR FORMATIONS OF THE SURROUNDING TERRITORIES.

From the reports of HAYDEN (1916) and BRÜCKL (1935), to which we referred in a preceding paragraph, it seems as if our Khandut formation, or a part of it, can be correlated to the *Wakhan Slates.* However, we thought it necessary to keep it distinct, both because of the presence of limestone in the former, and because of the lack of precise data for a correlation, as we do not know type-sections either of the former and of the latter.

With regard to the Wakhan Slates, it must be said that the stratigraphical position is subordinate to the accuracy of HAYDEN's statement (p. 311) that the Wakhan Slates are merely metamorphosed representatives of the *Sarikol Shales.* The position of the latter should be determined by their underlying to the *Pamir Limestone,* or rather to a limestone attributed, although without palaeontological proof, to the Carboniferous. However, this interpretation is not accepted by the Russian geologists who have studied the Pamir. We limit ourselves to mention here the opinion of V. VINOGRADOV given in the « Lexique Stratigraphique International » of the Soviet Union (1958), under the heading « Pamir Limestone »: « thich mass of limestones overlaying the so-called Sarikol Slates and belonging to the Triassic, Jurassic and Cretaceous. Recently it was realised that the Pamir Limestone is not a single and continuous mass. Under this name are wrongly gathered calcareous horizons of a series of formations separated by intervals from one another. This name has no stratigraphic meaning ».

We must also remember that neither above the Khandut Slates nor, as

far as one can understand from HAYDEN's writings, above the Wakhan Slates, outcrop a thick limestone beds of the type of the Pamir Limestone.

Another correlation may be attempted owing to a certain affinity of geological composition, with the *Misgar Slates* (DESIO & MARTINA, 1972) of the upper basin of the Hunza river in North-west Pakistan. This formation is fundamentally composed of a series, 5000 m thick, of black arenaceous slate with few intercalation of greyish arenaceous quartzite and some sills of porphyrite which seems to correspond to the Wakhan Slates. However, limestone intercalations are lacking in this formation, but there is another formation at the contact with the Misgar Slates (that is the Kilik Formation) composed of dark, thin-bedded limestone and dolomite separated by dark-grey arenaceous slate associated with brown sandstone and red arenaceous slate.

Could it be that Khandut Black Slates include the Misgar Slate and the Kilik Formation together?

We have not sufficient data to reply. It is only worth while adding that these two latter formations are to be found in a tectonic situation fairly similar to that of the Khandut Slates in the frame of the general structure of that territory (Desio, 1965b). If the correlation is valid, we can however only say that, as regards the age, this is a formation which could be attributed to the Palaeozoic.

Other lithologically similar formations are present in Badakhshan as we have seen in precedent chapters.

The same observation can be made about the Pamir where, in the area around Namangut, near the western boundary of Wakhan, black slates with fossils from the Triassic have been collected (N. A. KHOREV, 1956). The above confirms the difficulty of correlating the Khandut Black Slates with other formations composed prevailingly of black shales or slates, owing to the repetition of similar lithofacies, in different geological levels.

However, on the age of the Khandut slates we get another element of judgement regarding its relation with the Babatangi Granodiorite. As has been said, the black slates were metamorphosed by the granodiorite for which their age is evidently anterior.

We have no data on the age of this granodiorite, but the Tirich Mir Peak rises a short distance away and this is also composed of a granodiorite

comparable with that of the Babatangi, and in any case belonging, like the other, to the axial batholith of the central Hindu Kush, the age of which has been determined. The sample was taken by the 1964 expedition of Kurt-Diemberger on the southern slope of the group, and according to the determination effected by the Rb/Sr method at the Laboratory of Nuclear Geology at the University of Pisa, an age of 115 ± 4 M.Y. was given. This means, of course, the Lower Cretaceous, for which the Khandut Black Slates are to be considered pre-Cretaceous: at the moment we are not in a position to say much more. If we now attempt to correlate the other formations identified in south Wakhan, we find ourselves confronted with even greater difficulties. The lithological data at our disposal on the Qala Wust Gneiss are insufficient for an efficacious comparison with similar formations of surrounding territories, the more so as there are several gneiss formations in nearby Pamir and east Badakhshan.

A reason for comparison may be due to the metamorphic zoning of Alpine age which effect the Qala Wust Gneiss and in part also the black shales at the contact with the axial batholith of the Hindu Kush. Analogous conditions, above all as far as the biotite-garnet, biotite-orthoclase and plagioclase migmatite zones are concerned, have been met with in the metamorphic layers of south-western Pamir by A. G. Davydenko (1966) who considered them similar to the Wakhan series. According to this author this zoning was due to the thermal action of plutonic post-Jurassic masses.

4. OUTLINE OF THE LOCAL TECTONICS.

In Wakhan, as in many tectonized regions, often there are two distinct systems of tectonic dislocation of different size. The entire tectonic style of the territory depends on the principal or the first degree system, while the details of the tectonics of the region can be attributed to the second. We shall deal first of all with the principal.

We already mentioned the presence in the Amu Darya valley of a main dislocation line which the Russian geologists called the peripheric southern fault of the Pamir (Barkhatov, 1963). This fault, which roughly follows the river between Ishkhashim and Qala Panj, proceeds towards the east along

the valley of the Pamir river until it joins the Hunt-Alichur fault, which divides the tectonic zone of South-east Pamir from that of South-west Pamir, and, further east, from the Kara Chukur — Upper Hunza tectonic zone (Desio, 1965b).

The peripheric southern fault of the Pamir represents a deep and ancient scar of the earth's crust which separates two geotectonic systems substantially different in structure and history, the ancient cratonized block of South-west Pamir, and to the south the intensely corrugated geosynclinal belt of east Hindu Kush, of Cimmerian age, reworked during the Alpine orogenesis.

This is not visible in several points of the area visited in Wakhan, but it is well exposed in the neighbourhood of Zebak, where Desio was able to see along the fault-line a bed of friction breccia some hundreds of metres thick (page 287).

We have no data as to the size of the throw of the fault, but we are of the opinion that it may be some thousands of metres.

We mentioned beforehand the branching of the above fault to the east of the confluence of the Pamir river with the Wakhan river. In fact a branch could re-ascend the valley of this latter river and perhaps joins the Upper Hunza fault, but this is purery a working hypothesis as none of us had the opportunity of following the valleys of Wakhan and Little Pamir up to their sources.

As far as is known on the tectonic structure of the southern slope of the valley a decided parallelism can be pointed out in the trend of the tectonic lines and the stratigraphic units, for which on this slope the same formations are exposed for many kilometres at last for the stretch explored as far as the village of Rorunq. However it cannot be excluded, and we think it probable, that this is not a continuous stratigraphic series, but repetitions along overthrust planes and therefore rather sloping down.

We have already mentioned the small tectonic feature: two fault systems are present approximately perpendicular one to the other and with a N 50°-55° E and N 25°-30° W orietation. The first are mostly reverse faults, the second normal faults and they are more recent than the preceding ones.

On the whole, the territory results in being dissected by the two fault systems into irregular blocks prevailingly developed in east-west direction

that is to say parallel to the principal tectonic lines of the Pamir, Hindu Kush and Karakorum.

This tectonic structure fits in with the general scheme of this portion of Central Asia proposed by DESIO (1974b).

VI. TECTONICS

1. INTRODUCTION.

While knowledge of the tectonics in Pamir and Tadzhikistan has rapidly developed especially since the Second World War, knowledge of the structure of Badakhshan has remained mainly at the stage of extrapolation based on the information acquired in the above mentioned areas.

It should also be mentioned that in the large area comprising Pamir, Tadzhikistan and Afghanistan, Badakhshan covers only a relatively restricted area.

The first serious attemp to interpret the main tectonic structure of Badakhshan and its relationships with neighbouring territories based on data collected in the field was made in 1963 and was the first result of geological research undertaken by DESIO's Expedition which operated in Badakhshan in 1961. In the first preliminary report by DESIO, the existence of an assemblage of the Pamir tectonic zones resulting from the convergence of the main faults which divide the Pamir area towards the south-west, that is around Faydzabad, was recognized. In this study, as in the others which followed, the Pamir tectonic zones were correlated with those of Badakhshan and with those of the surrounding territories both to the east and west (DESIO, 1964b). Further details about the tectonics of Badakhshan appeared in later publications based on the expedition results, all of a preliminary nature. In particular, the geological map of Central Badakhshan at a scale of 1:150.000, published in 1964 by DESIO, MARTINA & PASQUARÈ, also included in this volume together with brief notes by the same authors, gives other details.

Only in recent years has a brief account by ARCHIPOV, LEONOV & NICONOV (1970) appeared, in which the tectonics of our area are discussed summarily, based on the information given by earlier authors (including preliminary information published by us) and data taken from original publications by the authors themselves. A sketch-map on the scale of 1:600.000,

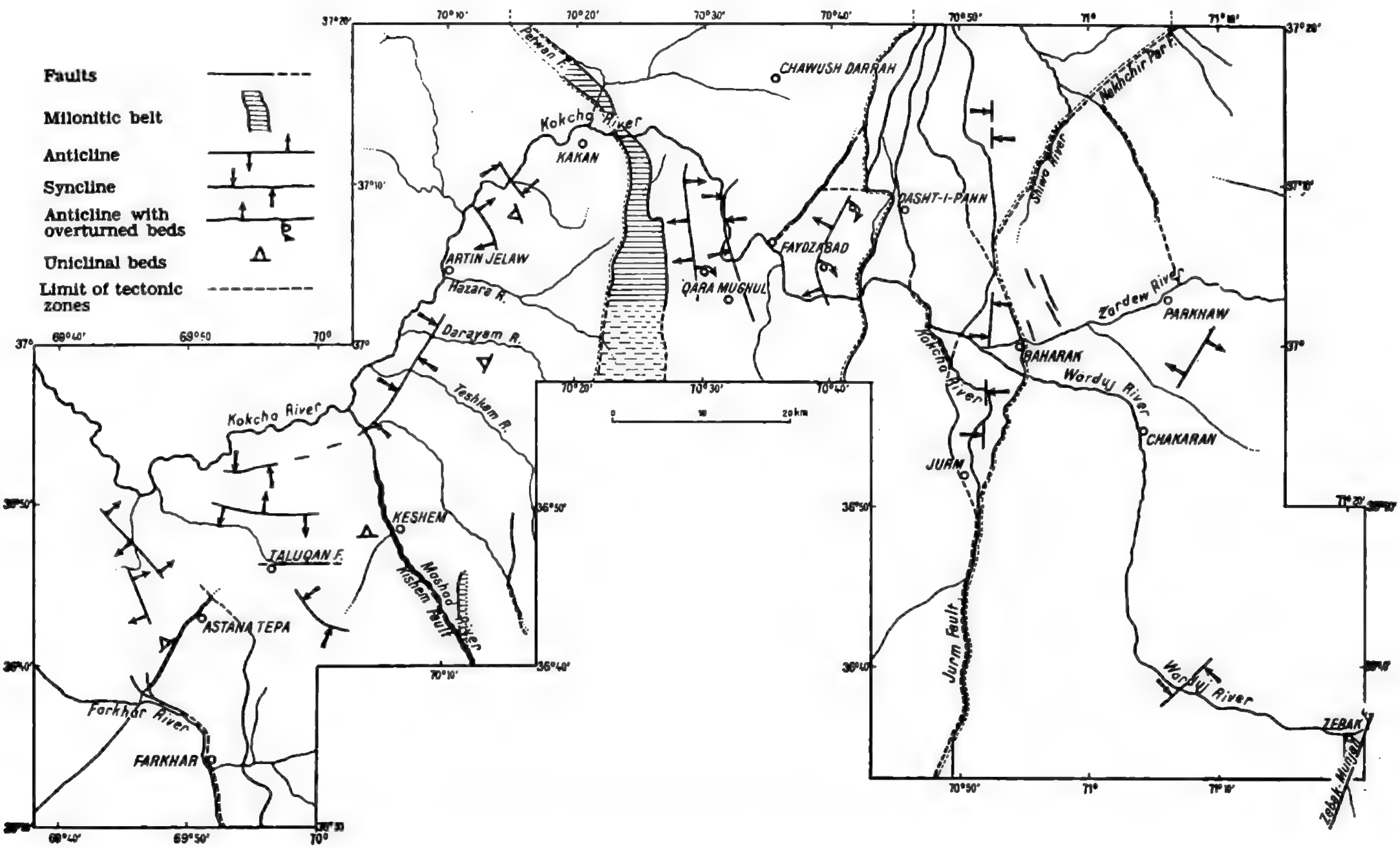


Fig. 40 - Tectonic skech-map of Central Badakhshan, from the surface geological survey of the DESIO's expedition. (The dashed lines mark the boundaries of the tectonic zones).

partly based on our geological map and on the tectonic sketch in which the tectonic zonation of western Pamir and Badakhshan also appears, is of particular interest to us. It must be mentioned here that the study by H. W. WELLMAN (1) (1966), which presents the fault pattern on a map based on an air-photo-mosaic of a very large area comprising Iran, Afghanistan and a part of West Pakistan, is very important for the interpretation of the tectonics of our area.

It is considered necessary to indicate in detail the concepts which we have adopted for the tectonic interpretation of our area and the factual data on which these are based. These latter data are illustrated in the following section and are graphically summarized in the tectonic map (Fig. 40) and the geological sections of fig. 41.

2. SHORT DESCRIPTION OF THE LOCAL TECTONIC ELEMENTS.

In the extreme south-western part of the area surveyed, that is between Khatayan and Gazestan, the sedimentary formations resting on the crystalline basement dip regularly and gently westwards. This trend is interrupted in the north-east by two branching and subparallel structures:

a) *Elftaw anticline,* situated between the village with the same name and Mir Badal striking SE-NW, with a core of Baba Darwes Formation limestones and the steeply dipping limbs composed of Kokcha Formation clastic deposits.

b) *Archa Kotal anticline,* located a little to the north of the pass of the same name, striking SE-NW, with a core of Baba Darwes Formation limestones and the Kokcha Formation steeply dipping limbs.

Other anticlines appear to have formed as a result of a high in the crystalline basement characterised by the presence of an intrusion of Jalmish Tonalite in the Farkhar Slate, outcropping just south of Astana Tepa. This characteristic structural style is present throughout the most westerly area

(1) This author did not take into account our notes and our geological map of Central Badakhshan included in the present volume but published in 1964.

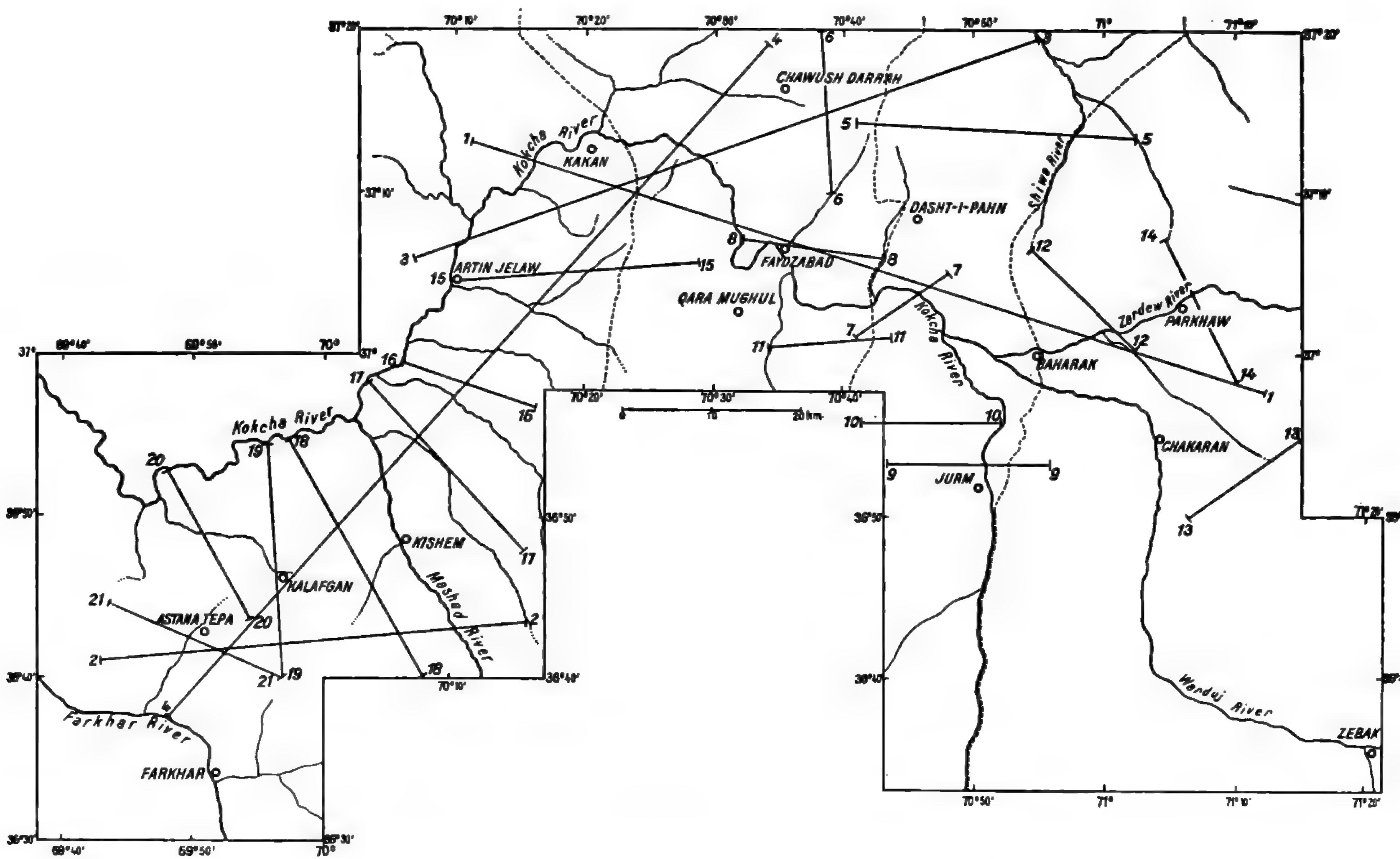


Fig. 41 - Tracing of the tectonic sections across Central Badakhshan. — Fig. 42 - Tectonic sections through Central Badakhshan. (The sections are enclosed at the end of the volume with the Geological Map).

studied (west of Kakan), where the sedimentary rocks overlying the crystalline basement follow his trend, that is plung towards the Kokcha valley. They gently repeat the swells and depressions in the crystalline rocks which are intruded at greater or lesser depth by plutonic bodies in the Farkhar Slate (Fig. 41 b, section 2).

On the right side of the Farkhar valley are found:

c) The *Shingan fault*, subvertical, striking ESE-WNW, which branches towards the NW. This fault is down thrown on the south-west and the Shingan Conglomerate and the Qara Bulaq Sandstone are in contact with the underlying Farkhar Slate.

d) *Khurmab fault*: this runs mainly in a north-south direction for about 20 km, a few kilometres east of the Farkhar river, placing in contact, tectonically, the Farkhar Slate and the Jalmish Tonalite. The contact is generally seen to dip towards the west, but in the Khurmab valley it dips steeply towards the east.

In the crystalline basement can be observed:

e) The *Kishem fault*, situated above (that is to the SSE) of Kishem striking NNW-SSE. This fault, on which the Mashad valley is imposed, places the Jalmish Tonalite in contact with the Naghz Darrah Tonalite 3 or 4 km SSE of Sang Ab.

f) The *Sang Ab fault*, which runs in a north-south direction north of Sang Ab village. The contact between the Farkhar Slate (to the west) and the Naghz Darrah Tonalite (to the east) is marked by a belt of blastomylonite and mylonite about 1000 m thick. Naturally the Farkhar Slate is strongly dipping and affected by local faults, as for example in the valley immediately to the east of Kangurchi. The same tectonic contact, still with a north-south strike, extends into the upper valley of the Wakhshi river (along the righ side) displaced, however, some kilometres to the east.

The course of the Kokcha river, in the area below Artin Jelaw, has a parallel trend, in broad terms, to that of the axes of certain folds that affect the Kokcha Formation. These axes are regularly aligned a few kilometres south of the river. In fact downstream from Darina, that is near the western border of the area mapped, the direction of the Kokcha is SE to NW, like the axes of the two anticlines of Elftaw and Archa Kotal, mentioned

above. Higher, between Darina and Artin Jelaw, the Kokcha runs first east-west, then WSW-ENE and finally SW-NE, that is parallel to the axes of three folds which are respectively:

g) *Jeldragh anticline,* located immediately north-west of the village of the same name, striking east-west with a core formed of Bluti Formation rocks and steeply dipping limbs of the Kokcha Formation (and the Baba Darwes Formation at Jeldragh).

h) *Chahar Tut syncline,* located between Sar Chashma and Chahar Tut, striking WSW-ENE involving only the Kokcha Formation;

i) *Ghelawuk syncline,* in the Kokcha Formation with the axis striking NE-SW and passing through Ghelawuk.

Above Artin Jelaw and as far as Qara Kamar, the Kokcha valley cuts two folds almost at right angles, that is:

j) *Gaji anticline,* in the Kokcha Formation, with the axis striking NE-SE and passing through the village of the same name;

k) *Sabzi Bahar syncline,* striking NW-SE in the clastic deposits of the Kokcha Formation, near Sabzi Bahar.

Above Qara Kamar, as far as Wular, the Kokcha river cuts the crystalline basement. In this tract about 50 km long, the following tectonic elements occur:

l) *Petwan fault,* an important regional tectonic discontinuity marked by the presence of the Petwan Blastomylonite. This belt, located between the Kakan Quartzdiorite (to the west) and the Halqa Jar Amphibolite (to the east), between Ishkashan and Samati is 1000-1500 m wide and strikes NW-SE with a 45° dip to the east. Towards the south the belt increases in thickness until it attains 6000 m at Hafez Mughul, while the strike changes towards the south;

m) *Halqa Jar anticline,* which extends for at least 15 km south of the Kokcha river, between Halqa Jar and Eran Shah; this fold in the Halqa Jar Amphibolite strikes north-south, and in the southern area is overturned towards the east;

n) *Qara Mughul syncline,* a fold in the Qara Mughul Gneiss striking SSE-

NNW and aligned south of the Kokcha river between Qara Mughul and Batash, striking north-south and then SSW-NNE north of the river (Fig. 42 b-c, sections 1 & 11);

o) *Naw Abad Fault,* located immediately NE of Faydzabad as far as Sar Darrah, striking SW-NE;

p) *Kaferan pass wedge,* elongated in a SSW-NNE direction for at least 20 km starting in the upper valley of Sum Darrah; comprising Devonian-Jurassic limestones squeezed between the Rabat Gneiss;

q) *Faydzabad anticline*: a large, important fold with axial plane plunging westward. Its core comprise the oldest and deepest rocks of the region (Faydzabad Gneiss). The axis of the structure, which crosses the Kokcha valley at Khanaqa, is orientated SE-NW south of the valley and SW-NE north of the valley itself. The eastern limb is formed of Rabat Gneiss, while the western one comprises the heteropic Qara Mughul Gneiss.

The area east of Wular, as far as Baharak, is characterised by a series of tightly folded anticlines and synclines striking NNE-SSW and formed mainly of Devonian-Jurassic limestones, black slates and Rabat Gneiss. Important sub-vertical faults with a general NNE-SSW strike affect these folds longitudinally, reducing them occasionally to simple slice extending for tens of kilometres (Fig. 42 b-c, sections 3,7 & 10). These faults are:

r) *Dasht-i-Pan fault,* from Wular to Koh-i-Sur Khan;

s) *Char-Su pass fault,* with a variable direction;

t) *Furmoragh fault,* with an arcuate trend along the Syah Jar valley, the Wuran Shahr pass and the eastern slope of Koh-i-Sur Khan;

u) *Jurm fault,* which passes immediately to the west of the village of Naw Jurm and which may represent the southern extension of the Furmoragh fault, south of the Baharak plain.

Between this series of faulted structures and the Baharak plutonic body one finds:

v) *The Shiwa river syncline,* striking NNE-SSW from the valley of the same name towards Naw Jurm, developed in black slates (Fig. 42 b-c, sections 1,5 & 9).

w) *Baharak fault,* the north-south arcuate outline which determines the contact between the black slates (on the west) and the Baharak pluton or the sialic granite-gneiss (outlet of the Zardew and Warduj valleys, Fig. 34) in which the presence of a series of small parallel faults can be seen and these are:

x) *Malang Ab faults,* striking NW-SE which near Wakh Shir reach and affect the neighbouring black slates.

Lastly, east of the Baharak Granodiorite (with associated granite gneiss and Tarang Gneiss) is found the:

y) *Koh-i-Chahil anticline,* located in the middle Kurkhu valley, with its axis striking NE-SW and with a core of Kurkhu Gneiss (Fig. 42 b-c, sections 1 & 14).

This is the bare outline of the main structural elements identified during the geological mapping undertaken in the territory studied. From an examination of the geological sections and the tectonic map it may not be easy to appreciate the relative importance of the individual elements and the role each plays in the regional tectonic scheme. This is true more of the faults than of the folds. These faults will be discussed below.

3. CRITERIA FOR THE TECTONIC ZONATION OF BADAKHSHAN.

Before presenting a subdivision of the tectonic zones of Badakhshan, on which correlations with the surrounding areas can be easily based, it is necessary to remember the criteria which have been used to unravel the tectonic zones of our area, without illustrating those criteria adopted by other authors in their analyses.

Obviously, the greater the knowledge of the stratigraphy and tectonics of an area, the easier it is to choose the criteria. It is necessary to remember for our part the tectonic divisions of Pamir, because Badhkhshan lies on the south-western tectonic extension as clearly indicated by Desio (1963-65). Moreover, Pamir has been better studied geologically than Badakhshan to date.

The subdivions most widely accepted by the geologists who have stu-

died the Pamir are those proposed by B. P. BARKHATOV (1963) in a very valuable work. The principles on which BARKHATOV based his tectonic analysis include the idea that the various tectonic zones are dependent on the palaeogeographical evolution. The main parametres adopted by BARKHATOV for his subdivision of the Pamir into tectonic zones and subzones can be summarised as follows:

1) the epoch when the development of the final geosynclinal phase ended for each tectonic zone:

2) the duration of evolution of the geosyncline after the Cambrian;

3) the predominant (positive or negative) character of the vertical movements which followed the end of the last geosynclinal phase.

It should be mentioned immediately, however, that in order to have a tectonic zone as understood by BARKHATOV which has a palaeogeographical evolution different from that of the neighbouring areas, it must be separated from these by long, profound and long-enduring fractures (geosutures). Only if these conditions exist, can an isolation of the tectonic zone take place from the neighbouring zones and thus allow a certain independence of palaegeographical evolution to occur.

It appears therefore that the primary element to consider is that of the presence of geosutures on which the division of the area studied into blocks depends. If the blocks are broken and disordered by a system of geosutures, it is obvious that their palaeogeographical evolution also developed in a more or less markedly independent way. It follows that the palaeogeographical evolution is a complementary parameter, or parameter which serves to control the previous one. It is possible to object that this reasoning can be reversed, but it is known today that geosutures are not necessarily inferred from the palaeogeographical independence of the tectonic blocks which surround them, but with geophysical methods, especially seismic and gravity surveys as well as, naturally, surface geology.

For these reasons, an attempt has been made to distinguish these geosutures in the area studied, to relate them to those known in the Pamir and then study their true tectonic significance in the palaeogeographical evolution of the areas which surround them. In practice it is sufficient to compare the stratigraphical sequences of the areas to achieve the same results: the stratigraphical sequences are in fact a detailed account of the palaeogeographical events to which the area in question has been subjected.

It is also possible to proceed in the opposite sense, moving from the best known towards the least known. One can move, therefore, from the already established tectonic zonation of Pamir and search in Badakhshan, among the tectonic lines observed at the surface, those that as a result of orientation and the geological characteristics of the surrounding areas are best adapted to represent the continuation of the above-mentioned geosutures.

It is obvious that in a fracture (and fault) system in a specific area there is normally a certain rank depending on the depth, length and permanence through time of the fractures and faults. If, as already mentioned, the longest, deepest and persistent fractures characterize the principal fractures, those with the same but less developed characters, would serve to break up the area into tectonic subzones.

It is worthy of note that the emergence of the fractures at the surface depends on particular circumstances often related to the geomorphological evolution of the area.

If account is taken of the evidence presented above it is apparent that the tectonic subdivisions of Pamir can be applied to Badakhshan. These subdivisions are presented here in summary from the work of BARKHATOV especially from his 1963 monograph, which appears to be valid still in large part (1).

4. THE PAMIR TECTONIC ZONES.

According to BARKHATOV and others, the Pamir area can be divided into four tectonic zones, bounded by deep peripheral fractures or faults. The most important of these, the *Wanch-Akbaytal fault*, separates the Palaeozoic structures of the Norhern Pamir from the adjacent predominately Mesozoic-Cenozoic tectonic zones. These structures are succeeded to the south by the Central Pamir which is separated from the South-eastern Pamir by the *Rushan - Pshart fault*. The South-western Pamir lies further south and is structurally independent. It is separated from South-eastern Pamir by the *Hunt-Alichur fault*.

(1) BARKHATOV's general tectonic scheme is to be found with only slight modification in the respective tectonic maps in the « Atlas of the Tadzhikistan Soviet Socialist Republic » published by the Nauk Academy of Tadzhikistan in 1968.

North of the area mentioned above there is another Palaeozoic tectonic zone, the Pamir-Alay.

The southern boundary of these Pamir tectonic zones is marked by the *Southern Pamir fault.*

1. The *North Pamir zone* belongs to the Kun Lun orogenic system which was affected by a main phase of diastrophism during the Hercynian orogeny (Permo-Triassic), but later was affected by the events of the Mesozoic-Cenozoic geosyncline. However, the Alpine orogenic phase the « Karakorum phase » (as it is called) did not produce any independent tectonic effects.

2. The *Central Pamir zone* was affected by a developing geosyncline from the Early Palaeozoic to the end of the Mesozoic and the Alpine orogeny produced the central meganticlinorium with very complicated folding.

3. The *South-eastern Pamir zone* was affected by palaeogeographical and tectonic events analogous to those of the previous zone, but the geosynclinal stage began in the Late Palaeozoic. The structure is relatively simple because the Precambrian crystalline basement lies at shallow depth. The plutonic and volcanic rocks are related to the Alpine orogeny. The structures of Alpine age form a mega-synclinorium.

4. Finally, the *South-western Pamir zone* comprises a crystalline massif of Precambrian age, which did not undergo any substantial transformation during the subsequent orogenic phases.

The old age of the crystalline basement in Central Pamir is contested by E. J. Leven (1963). Also the age of the crystalline massif of the South-western Pamir has to be partially altered in accordance with the results of some radiometric age determinations (L. L. Shanin et al. 1969), but the tectonic scheme still stands.

5. THE MAIN FAULTS IN BADAKHSHAN.

Our research into the surface geology has resulted in the recognition of numerous faults in Badakhshan, of which only some play an important role in the regional tectonics. Particular importance must be given to these

tectonic lines which, as in Pamir, determine the limits of the tectonic zones into which the area surveyed can be divided (Fig. 43 and 46).

a) The *Zebak-Munjan fault* passes through the south-eastern part of the region studied about two kilometres from Zebak village and is aligned between NE and NNE and the dip of the fault plane is almost vertical. A thick layer of mylonite which accompanies it indicates the importance of the dislocation (page 287 and Plate VIII, fig. 1 & 2). Above Zebak the fault follows the Sanglich valley as far as the pass of the same name and then runs towards Shar-i-Munjan and the Panjshir valley.

The Zebak-Munjan fault is also indicated in a report by P. BORDET & A. BOUTIÈRE (1968). According to these authors it passes through the village of Zebak in a north-south direction deviating just below it towards the NE to pass near the village of Zar Khan. Above, it runs along the right flank of the Sanglich valley where it is clearly visible and beyond the pass of the same name it runs along the right flank of the Tegao valley and ends near Shar-i-Munjan.

It should be noted only that, near Zebak or below, the line of fault indicated by the two authors runs through an area covered with alluvium and moraines and thus should be considered hypotetical. According to the data we have collected around Zebak (page 288), the fault passes south-east of the village, as already mentioned.

The Zebak-Panjshir-Ghorband fault is here interpreted as the western extension of the South Pamir fault of BARKHATOV (1963) and as the eastern extension of the « Ghorband line » of BRÜCKL (DESIO, 1960) and the Gorband-Panjshir-Anjuman line of DESIO (1965 b). It agrees, therefore, in a general way with the eastern part of the Herat fault of WELLMAN.

In WELLMAN's fault pattern, two lines of dislocation converge near Zebak, the main one, with a north-easterly strike, represents the eastern part of the Herat fault, the other secondary one with a NNE strike, which, in order to distinguish it will be called the *Sarobi-Zebak fault* [1], probably represents the north-eastern part of the Gardez fault of HEUCKROTH & KARIM (1970) and intersects the previous one about 40 km south-west of Zebak, passing at a short distance to the west of the village. A second rather short fault fol-

(1) Towards the south-west it passes near Sarobi village on the motorable trail Kabul-Peshawar.

lows a line which bisects the angle formed by the two faults discussed above, extending towards the north-east.

It can be asked at this stage which of the lines indicated by WELLMAN corresponds to the Zebak-Munjan fault. The presence of a great thickness of mylonite and the series of thermal springs in the Sanglich valley (BORDET & BOUTIÈRE, 1968) underlines it and suggest that it is the most important dislocation, that is the Herat fault. However, the Herat fault, according to WELLMAN's scheme, passes some fifteen kilometres south-east of Zebak, while the Zebak-Munjan fault passes less than two kilometres from the village mentioned above. In strike and topographic position the Zebak-Munjan fault seems to correspond either to the Sarobi-Zebak or the secondary fault which bisects the angle between the two main faults. As mentioned above, however, the presence of a considerable thickness of mylonite and thermal springs do not support these interpretations.

It can thus be suggested either that the line indicated on WELLMAN's map must be changed near Zebak by moving it several kilometres towards the north-west or that two faults equivalent to the Herat fault exist, one near Zebak, the other to the south-east. Both probably join eastwards in the Ab-i-Panj valley floor and connect through a wide arc with the South Pamir fault of BARKHATOV. The fact that near Zebak WELLMAN's fault line is dashed, suggest that in this part the position was not determinable on the aerial photographs, however the second hypothesis also appears sufficiently credible.

b) The *Shiwa fault* is represented by a boundle of faults with strikes varying between NE, N and NW.

Our studies of the Lake Shiwa area were not sufficiently extensive to distinguish the various faults which intersect this zone and moreover the vast mountainous area which extends SW from the lake is unknown. An important fault recognized by us cuts diagonally across the Nakhshir Par valley (*Nakhshir Par fault*) about 12 km from Lake Shiwa where a mass of granite, mylonitized in part, outcrops in contact with blac kslates. It strikes SW and its south-westerly extensions passes into a black slate area where it is poorly recognized because of the plastic characteristics of these rocks.

Two other faults are clearly visible in the mountains which rise north of Lake Shiwa, one striking NNE, the other ENE. Bands of mylonite orientated NE are present in the central part of the area under consideration,

but their south-westerly extension is not known. The Zardew valley, which runs further to the south, is crossed by various faults with strikes which range from N-S to NW and these probably join, at least in part, with those of Shiwa and then extend southwards, that is towards the upper Warduj valley. Various faults cut this valley also, but we were unable to determine how they are linked to these established further north.

According to our interpretation (DESIO, 1964), the Shiwa fault starts in the convergence of the Hunt-Alichur fault with the Rushan-Pshart fault of BARKHATOV. In this connection it is interesting to note that between the faults indicated by WELLMAN in the NE corner of his map, the Shiwa fault appears again extending NE of Shiwa more or less along the Rushan-Pshart fault. Then the fault deviates at a point where the Rushan-Pshart fault bends ENE to join the Bartang fault of BARKHATOV, a secondary fault, which towards the NE joins with the Wanch-Akbaytal fault, one of the most important dislocations in the Pamir.

According to WELLMAN a secondary fault, corresponding to the Nackhshir Par fault, about 70 km long and trending NE-SW continues with some interruptions towards the NE into the Pamir following for a certain distance the Jasgulem fault of BARKHATOV. Towards the SW, another fault reported by WELLMAN, having the same trend, starts near Jurm and possibly represents the continuation of the fault entering the Pamir (Jurm-Anjuman fault) which will be discussed later. If, as it appears, it is only one fault, which could be called the Jasgulem fault, its lenght would be at least 360 km.

c) The *Jurm Fault* (DESIO, 1965b) is also formed by a fault belt and it is well recognizable to the north of Jurm where it follows the contact between formations of different ages. This is also shown in the geological map enclosed with the present volume (1). The fault belt strikes mainly north-south and towards the south merges into one fault which seam to follow the upper Kokcha valley above Jurm village. The « Jurm fault », an active fault belonging to WELLMAN's group originating near Jurm village, was named by HEUCKROTH & KARIM (1970) and continues for about 120 km in a SSW direction.

This fault however, does not correspond topographically with the « Jurm fault »

(1) To the north of the area explored by DESIO's expedition some geological data are published by LEONOV (1969).

(DESIO, 1964) which has a prevalent north-south trend and — as already mentioned, — seams to follow the upper Kokcha valley. The real Jurm fault forms an angle of about 20° with the fault mentioned by WELLMAN and, instead of extending towards Munjan, continues towards Anjuman traversing at a high altitude the left slope of the Jurm valley. It was impossible to follow our Jurm fault in the upper Kokcha valley and therefore the exact location is unknown.

Also it must be added that to the north of Jurm the position and trends of the faults observed by us in the field do not correspond to those shown on the map by WELLMAN. At present in order to avoid misunderstandings, since the Jurm fault of WELLMAN and HEUCKROTH & KARIM passes very near Anjuman, it could be called *Jurm-Anjuman fault* while our Jurm fault could be called *Jurm-Munjan fault*. Further investigations are however needed to solve this problem.

According to DESIO (1964) the Jurm fault represents the continuation towards the south-west of the Wanch-Akbaital fault of BARKHATOV.

d) The *Petwan fault* is represented by a belt of blastomylonitic and cataclastic rocks having a width from one to six kilometres and bounded on both sides by faults. This belt has an irregular orientation generally N-S and represents the western tectonic contact between Central Badakhshan and Kataghan. It was impossible to follow this mylonitic belt south of 37° parallel N (1). This belt undoubtedly represents a geosuture and possibly continues towards the south for several kilometres joining with the faults and the blastomylonitic and mylonitic belt of Sang Ab (spring).

One of these faults was observed in the field and passes near the villages of Taluqan and Kalafghan (*Taluqan fault*). It is probably more extensive than is visible in the field because it disappears under recent deposits. This fault is one of many faults having similar trends which probably bound the Upper Amu Darya Depression.

Many other faults were observed on the southern slopes of the same depression having N-S or NW-SE orientations which differ from the trends of the precedent faults. One of the most important ones shows a belt of mylonite and traverses the eastern slopes of the Kishem valley and cuts towards north the Sang Ab village (*Sang Ab fault*); one of its branches follows the Kishem valley (*Kishem fault*). Both faults mentioned above mark the contact between the Jalmish Tonalite of Hercynian age and the Naghz Darrah Tonalite of Kimmeridgian age. Another fault of this group strikes N-S pas-

(1) The topographic maps of the area were not available.

sing near the village of Kashan (*Kashan fault*) and separates the same Hercynian pluton from the Farkhar Slates to the east of the lower Farkhar valley. The Kashan fault disappears towards the north under Neogene and Pleistocene deposits; towards the south it was not observed.

In the maps by WELLMAN no fault is shown at the location of the Petwan fault, but the Taluqan and Kishem faults are represented. WELLMAN reports two faults sub-parallel to the Jurm fault which are located between the latter and the Kishem fault. These two faults, generally parallel to the Khwaja Muhammad range, cross a region which was not visited by us. The south-eastern one is located near the crest, the other about 20 km to the NW. The former could be called the *Khwaja Muhammad fault,* the latter the *Chambuck fault* from the name of the village in the upper Kishem valley. These two faults are mentioned here because the Chambuck fault could represent the southern continuation of the Petwan fault.

It was necessary to refer to the faults reported by WELLMAN in order to complete our incomplete field-data. It must be taken into account, however, that the reason why some of our faults do not appear on the maps by WELLMAN could probably be that these faults lack superficial topographic expression recognizable on the aerial photographs; minor displacements in their location could depend on the use of different topographic maps. It can therefore be concluded that both types of faults are generally present. The presence of both types provides confirmation of their existence while the presence of only one of them does not invalidate their presence.

HEUCKROTH & KARIM compared the maps by WELLMAN with the geological map of Afghanistan and found that the largest discrepancies are present in the northern and eastern parts of the territory. This is easily understandable if the two different types of investigations carried aut are compared.

6. TECTONIC ZONES OF BADAKHSHAN.

The various tectonic zones present in the territory investigated can be easily recognized if the principal dislocation above mentioned are taken as a basis for such zonation. Furthermore, if consideration is taken of what has been said about their relationships with the principal dislocation lines

of Pamir, their correlation with the tectonic zones of that region can easily be recognized. This zonation, proceeding from the south-east towards the north-west, can be outline as follows:

1. Mountainous region of Hindu Kush,
   1a. Zebak-Munjan fault,
2. Eastern Badakhshan,
   2b. Shiwa fault,
3. Central Badakhshan,
   3c. Jurm fault (1),
4. Western Badakhshan,
   4d. Petwan fault,
5. Northern Kataghan — Upper Amu Darya Depression.

Only a small part of the first zone, however, is an integral part of Badakhshan; the last one is completely outside Badakhshan and its southern part belongs to Kataghan and the Upper Amu Darya Depression. First of all, the three tectonic zones belonging to Badakhshan will be discussed here, namely: Eastern, Central and Western Badakhshan; then the tectonic zones of Kataghan (see Fig. 40).

(1) *Eastern Tectonic zone* lies to the east of the Shiwa fault. As already mentioned in the previous paragraph, the belt of dislocations traversing the Lake Shiwa region and the Zardew and Warduj valleys has not been sufficiently studied; therefore the western limit of this tectonic zone is at present badly defined. In this zone, however, the East Rabat Gneiss containing frequent calcareous intercalations is predominant and appears to dip under the Kurkhu Gneiss which in turn underlies the migmatitic Tarang Gneiss. Both the East Rabat Gneiss and the Kurkhu Gneiss are folded in anticlinal and synclinal structures and are occasionally faulted. The fold axes are generally oriented NNW-SSE. A large pluton of Baharak Granodiorite is present on the western side of this tectonic zone to the north of the Zardew river. The pluton passes eastwards into Tarang Gneiss.

(2) *Central Tectonic zone.* This zone lies between two zones consisting

(1) In the division of Badakhshan it is not necessary to determine which of the two dislocation lines mentioned previously marks the boundary of this zone.

mainly of gneissic formations with which much younger plutonic rocks are associated. This Central zone contains only sedimentary formations such as the Kalawch Limestone of Devonian and Carboniferous ages, the Furmoragh Shales (Late Triassic) and the Wuran Shahr Limestone (Late Jurassic). The beds are folded and strongly faulted; the strike of the fold-axes and faults is north-south.

Proceeding from north to south the width of this tectonic zone becomes narrower and is considered to be a synclinorium.

(3) *Western Tectonic zone.* This zone is characterised by the Faydzabad anticlinorium the core of which is formed by the Faydzabad Gneiss, the oldest rocks outcropping in this region (Figs. 41 & 42 c). The outcrops (Faydzabad Gneiss, West Rabat Gneiss, Qara Mughul Gneiss, Halqa Jar Amphibolite) and the fold-axes are generally orientated between N-S and NNE-SSW as in the eastern zone. The fold-axes change direction to the north of Faydzabad where they occur near a mass of plutonic rock which acted as an obstacle to the tectonic movements.

The formations overlying the Faydzabad Gneiss on the opposite sides of the Faydzabad anticlinorium have different facies: the East Rabat Gneiss is replaced, on the western side, by the West Rabat Gneiss and by the Qara Mughul Gneiss. The Halqa Jar Amphibolite probably represents here a volcanic formation of early Carboniferous age outcropping in north-western Badakhshan according to the Russian geologists (Arkipov, Leonov & Nikonov, 1970).

The *Kataghan Tectonic zone* extends from Kakan towards Taluqan. In this region the formations (Farkhar Slates and Cretaceous and Tertiary formations) generally have a prevailling north-south strike in the east and a strike varving from north-east to east-west in the west. In the same region a large igneous body is present between Farkhar, Ganda Qol and the Kishem valley; a belt of igneous rocks striking approximately NNE-SSW is present also between the Halqa Jar Amphibolite to the east and the Farkhar Slates to the west, extending from Kakan as far as the Kishem valley. It is a lense-shaped intrusion accompanied by blastomylonitic facies which represents an important element in the geological structure and history of this region This intrusive body consists of tonalite which was probably intruded along a stratigraphical and tectonic discontinuity on the western side of the Faydzabad anticlinorium between the Halqa Jar Amphibolite and

the plastic black slates which acted as an impenetrable barrier to the intrusion. To the north-west of Faydzabad, where the Halqa Jar Amphibolite is best developed, the orientation of the igneous rocks becomes NNW.

It has already been mentioned that the mylonitic band of Petwan forms, towards the west, the boundary between Badakhshan and Kataghan which in turn tectonically belongs to the Upper Amu Darya Depression and therefore to a different tectonic zone.

It must be added here, however, that northern and southern Kataghan are different. The southern part represent the tectonic and orographic framework of the Upper Amu Darya Depression and towards the west could form a tectonic zone adjacent to those mentioned above. Regionally, the territory described above is located in a very complex tectonic area. It lies where the tectonic structures forming the Pamir converge in the south-west and is also very near the area where these structures come in contact with those forming, towards the south, the Hindu Kush mountain range. The relationships between Badakhshan and Pamir will now be discussed.

7. TECTONIC RELATIONSHIPS BETWEEN BADAKHSHAN AND PAMIR.

The tectonic relationships between Badakhshan and Pamir were outlined several years ago (Desio, 1963). It is necessary to mention them here because they will be used to clarify many structural characteristics of the two regions. It is also useful to mention here the simple considerations used by Desio to determine these correlations. If we succed in finding in Badakhshan the continuation of the two extreme (northern and southern) peripheral fractures of Pamir, within which that region is comprised, we can state which parts of Badakhshan are to be related to the tectonic zones of Pamir. The northern peripheral fault dividing the Pamir-Alay and the Northern Pamir tectonic zones also separates, to the south, the Upper Amu Darya Depression (Tuayev, 1961) from the mountainous area of Badakhshan. The same fault marks the western contact between the Cenozoic and older formations.

In Badakhshan, the line separating the Upper Amu Darya Depression from the Tertiary deposits and from the mountainous region composed

mostly of older rocks, crosses the Kokcha river west of Kakan. Therefore Badakhshan is located to the east of the extension of the Northern Peripheral Fault of Pamir.

On the other hand, the fault to the south of the South-western Pamir tectonic zone meets the Amu Darya (Panj) near Ishkhashim, a few kilometres from Zebak, where it joins the Zebak-Munjan fault. The latter, with a slight western deviation, continues westwards trending parallel to the Hindu Kush ridge for many kilometres. This tectonic line forms the south-eastern boundary of Badakhshan as well as of Pamir. It is obvious that Pamir and Badakhshan are located between the above mentioned peripheral faults. Between the two peripheral faults the Pamir has a rather uniform width of about 260 km whereas in Central Badakhshan the distance between the same faults is reduced to only 115 km. This means that the tectonic zones of Pamir are narrowed westwards to less than one-half of their width. The Badakhshan region therefore lies within the same tectonic features as those delimiting Pamir.

The tectonic subdivisions established within Pamir must be correlatable with those indicated within Badakhshan because one region represents the continuation of the other and viceversa. It is only necessary therefore to compare the principal faults of the two neighbouring regions in order to establish a tectonic correlation between Pamir and Badakhshan. The tectonic sketch reproduced in the Geological Map of Central Badakhshan (accompanying this volume) shows the main correlations between the tectonic zones of the two region as indicated below, proceding from east to west in Badakhshan, from south to north in Pamir ([1]):

1. *Hindu Kush tectonic zone*;
   1a. Zebak-Munjan fault (Herat fault) → South Pamir fault;
2. *Eastern Badakhshan tectonic zone* → *South-west Pamir tectonic zone*;
   2a. Shiwa fault → Hunt-Alichur and Rushan-Pshart faults;
3. *Central Badakhshan tectonic zone* → *Central Pamir tectonic zone*;
   3a. Jurm fault → Wanch-Akbaital fault;
4. *Western Badakhshan tectonic zone* → *North Pamir tectonic zone*;
   4a. Petwan fault → North Pamir fault.

The tectonic sketch, published about ten years ago, is not up-to-date, but it serve for the location of the tectonic zones.

5. *Kataghan tectonic zone → Upper Amu Darya Depression tectonic zone.*

It is not necessary to give any more details in order to confirm the similarity between the tectonic zones of both regions. If the stratigraphic correlations mentioned above are taken into consideration it is possible to determine that the geological history of the tectonic zones is almost the same as those in Pamir.

8. SEISMICITY AND TECTONICS IN BADAKHSHAN.

Specialized research was not carried out by DESIO's expedition on this subject, however it cannot be ignored because the region studied includes one of the world's most interesting seismic areas. GUTENBERG & RICHTER in their monograph on the seismicity of the Earth refer to this area as a r e m a r k a b l y p e r s i s t e n t s o u r c e o f e a r t h q u a k e s. The area, located in the southern part of the region studied, is close to the Hindu Kush (1) and is included in the rectangle formed by the 70° and 72° meridians east of Greenwich and the 36° and 37° parallels north, as confirmed by the extensive, recent research of HEUCKROTH & KARIM (1970).

This region, together with north-west Burma, is the only one where intermediate to deep earthquakes occur in continental areas: everywhere else they occur in fact near the oceanic trenches.

The main seismological feature of southern Badakhshan is the exceptional frequency and restricted spatial distribution of powerful deep earthquakes the cause of which has not yet been satisfactory explained. On this subject research has been done by H. L. SHIROKOVA (1959), G. D. PANASENKO & MESHKOVA (1964), A. R. RITSEMA (1966), L. E. HEUCKROTH & R. A. KARIM (1970, 1973), A. A. NOWROOZI (1971) and several other authors (2).

The intention of this section is only to gather from the above-mentioned publications information which can be used to better understand the tectonic structure of the area studied.

(1) All the authors who have studied the earthquakes of this region speak of Hindu Kush earthquakes, although they refer to a relatively small area on the northern foot of this chain. It would be more accurate to speak of southern Badakhshan which coincides reasonably well with the seismic area.

(2) A detailed bibliography appears in the publications of the above-mentioned authors.

Some authors examined the earthquake recordings from movements originating in southern Badakhshan and tried to establish the position of the epicentres and the earthquake magnitudes in order to interpret the mechanics.

The most detailed study of Afghan earthquakes was completed in 1970 by HEUCKROTH & KARIM who collected all the existing data, both historical and instrumental, up to 1969.

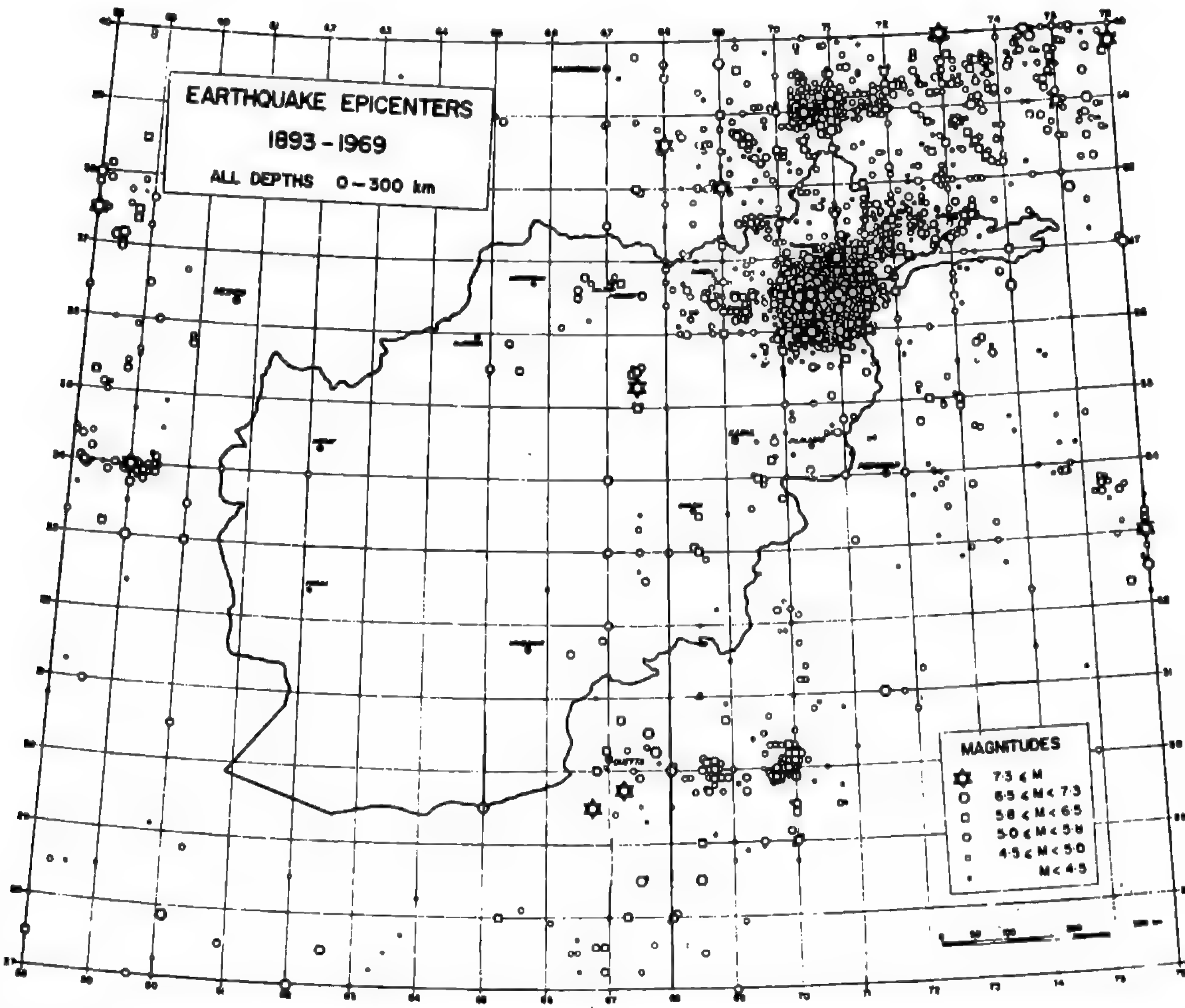


Fig. 43 - Geographical distribution of the earthquake epicenters in Afghanistan from 1893 to 1969, according to HEUCKROTH & KARIM (1970).

A series of sketch maps illustrates the epicentre distribution during the various periods of time considered. For the period 1893-1969, the highest epicentre density occurs inside an area included between 35.5° and 37° lat. N and between 70° and 72° long. E with an extension in a north-easterly direction which penetrates South-west Pamir for several kilometres. Another area

of high density appears to the north, straddling the 39° N parallel and between the 70° and 72° E meridians. This corresponds to the Wakhsh seismic area (Fig. 43). In this area, however, deep foci earthquakes are absent.

It is of particular interest to note the various detailed maps relating to the period from 1960 to 1969 and the different depths of the foci. The highest epicentre density is related to foci depths greater than 200 km. This is situated in a well defined area between 36° and 37° lat. N and between 70° and 71.3° long. E. This is a little over 11.000 km^2 in extent. In this area shallow earthquakes with epicentres from 0-70 km are almost totally absent and those related to deeper earthquakes increase gradually in number with the depth. The sketch-map showing the distribution of the seismicity for the same period, reproduced in Fig. 43, shows two seismic areas of shallow depth foci separated by an area without epicenters corresponding to the mountainous chains of the Hindu Kush and Karakorum. Moreover, in the southern Badakhshan the extent of earthquake activity converges with increasing depth.

Generally speaking, it can be noted that while the shallow earthquakes, originating in the Earth's crust, are distributed throughout most of the region, except for the belt corresponding to the main mountain chains, the deeper earthquakes originating in the upper mantle are restricted to a « pocket zone » south of Faydzabad where shallow earthquakes are almost absent (Fig. 44).

According to Shirokova (1959) earthquakes having the highest concentration of foci in the southern Badakhshan are caused by horizontal compressive stress orientated at right angle to the axis of the mountain chain and by vertical tensile stress. Panashenko & Meshkova (1964) have defined the direction of the compresive stress from south to north, suggesting the existence, in a not very remote geological period, of powerful pressures directed from the Hindu Kush towards the stable mass of Tien Shan. These pressures may also have been responsible for the folding in the interposed Pamir region.

Ritsema (1966) by comparing the average axial positions of a certain number of shallow and deep earthquakes, found that, while in the shallower group the main stress component is orientated almost perpendicularly to the structural trend of the Hindu Kush, an acute angle is formed between these two directions in the axis of the deep earthquake group.

Further, according to Ritsema, plane oriented approximately SW-NE with SE or NW dip and an inclination of 45° or more with corresponding strike-slip components, while for the deep earthquakes the general fault plane strikes ESE-WNW and the dip is either 25° N or 65° S; strike-slip components are in this case negligible.

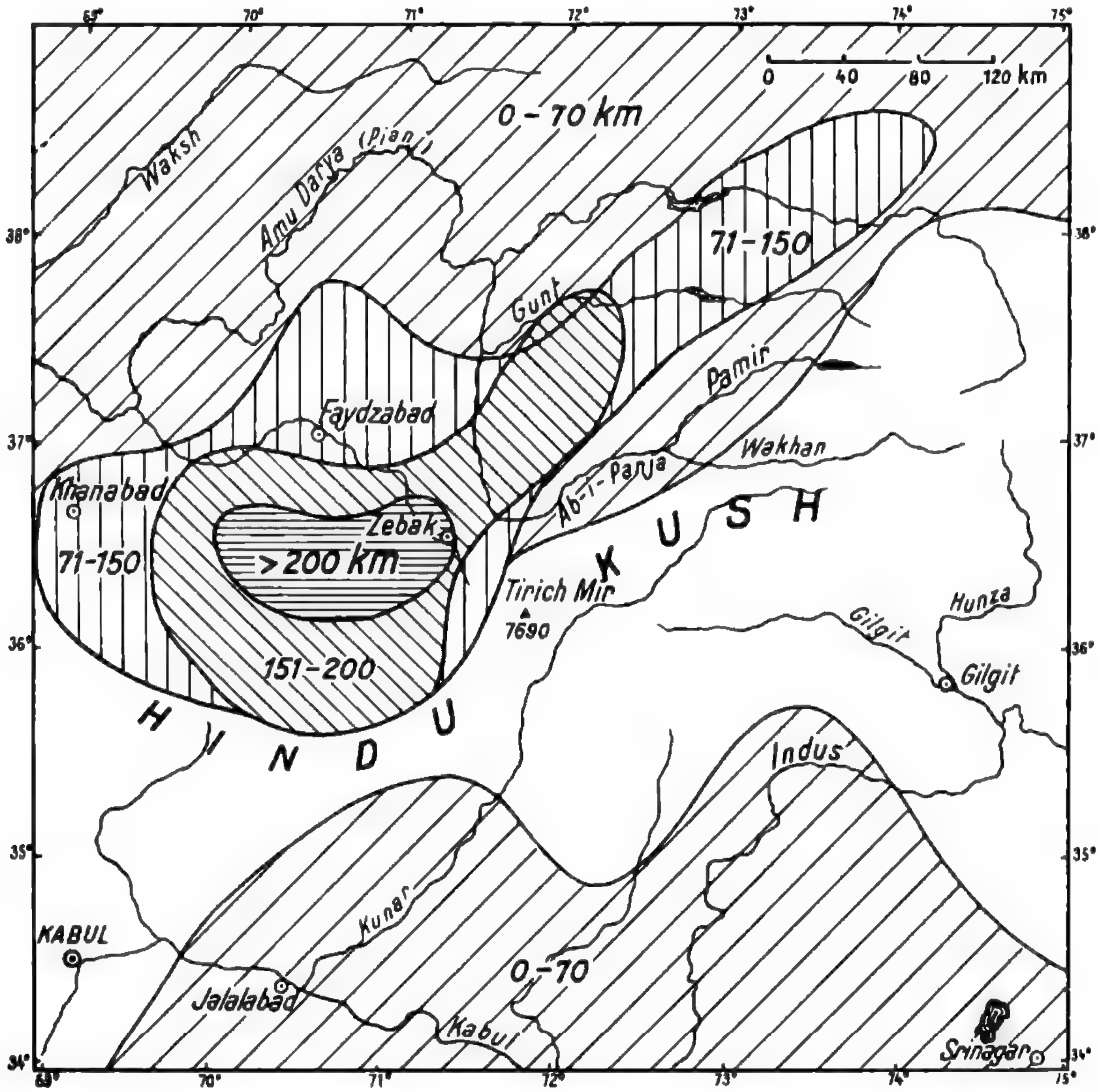


Fig. 44 - Distribution of the seismicity in north-east Afghanistan, according to Heuckroth & Karim (1970).

These data demonstrate, among other things, that both deep and shallow earthquakes originate from independent mechanisms. In other words, the tectonic processes active in the Earth's crust do not appear to be, in this case, directly connected with those of the upper mantle.

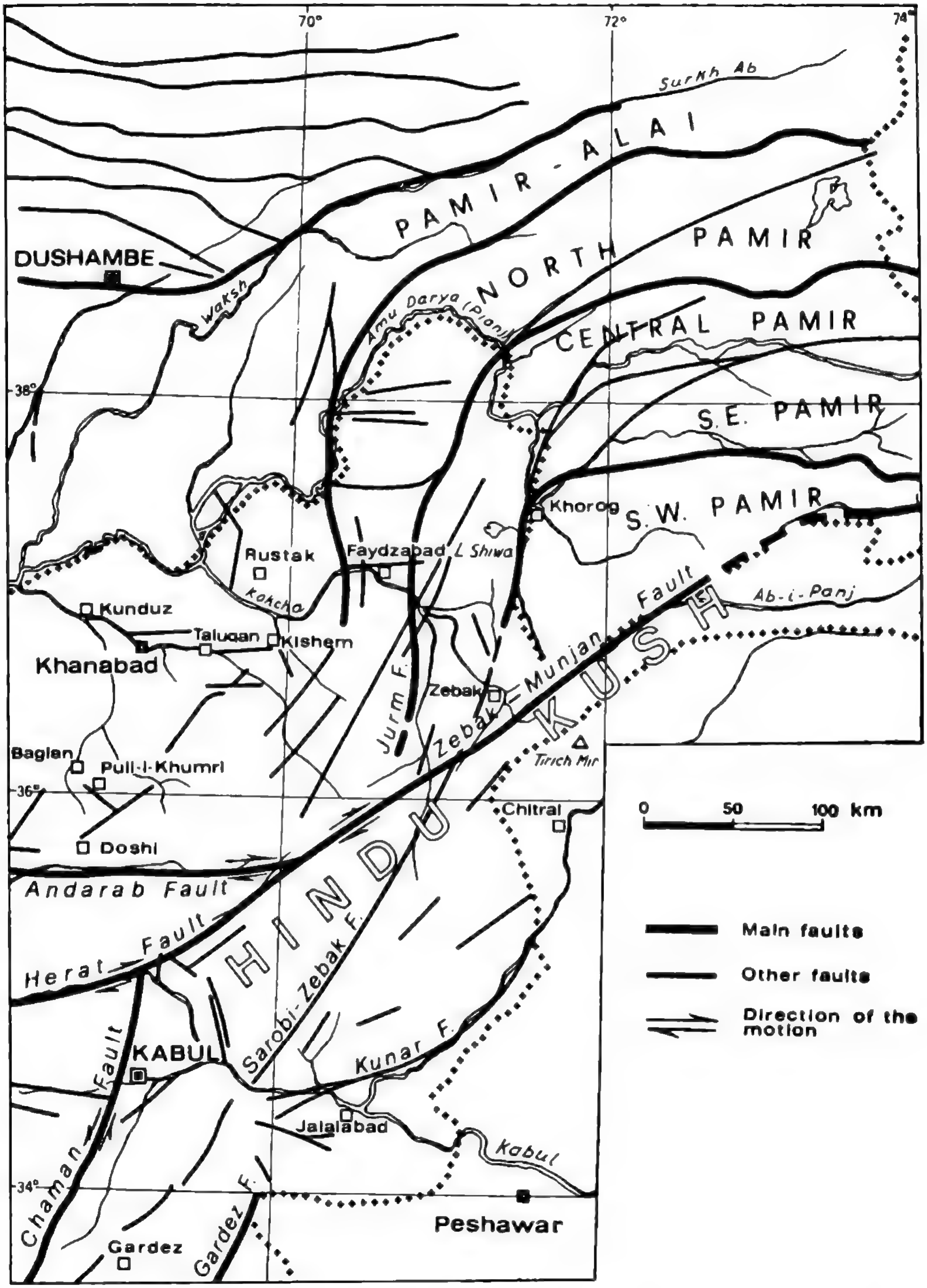


Fig. 45 - The main faults of north-east Afghanistan according to WELLMAN (1966), RITSEMA (1966), DESIO's expedition (1961) and the the *Atlas of Tadhzik S. S. R.* (1968) for the area outside Afghanistan.

According to NOWROOZI (1971) most of the earthquakes in the southern Badakhshan originate in a contorted slab-like feature located at a depth of 50 to 150 km extending in a north-easterly direction and up to 280 km in an east-west direction. This contorted slab, which includes the great majority of foci, is probably sinking into the mantle as a result of its greater density.

Thus a geotectonic interpretation of the peculiar seismic situation of the southern Badakhshan is introduced.

HEUCKROTH & KARIM (1970) tried to relate the results of the seismic investigation in Afghanistan to the structural pattern of the Indian Ocean (LE PICHON and al. 1968), and to WELLMAN's model of active wrench faults of Iran, Afghanistan and western Pakistan. The Afghanistan appears to be situated in a peculiar position, that is within the apex of the north-western corner of the Indian-Australian crustal plate. HEUCKROTH & KARIM postulate that the Chaman and Gardez faults, which strike north-northeast and are sinistral sense, form the north-western boundary of that crustal plate. Moreover WELLMAN's fault pattern delineate a minor continental plate of Iran, Afghanistan and western Pakistan, limited in eastern Afghanistan by the transcurrent Herat dextral fault toward north, and the Chaman-Gardez transcurrent sinistral faults to the east.

To the east of the Gardez fault the earth crust is driven to move toward NNE, that is in the same direction of the Owen fracture, and is thrust into the corner formed by Himalaya and Hindu Kush.

The direction of the thrust was determined by HEUCKROTH & KARIM utilizing different hypothesis, but all yelded directions NE to NNE. Similar directions for the intermediate-depth earthquakes of southern Badakhshan were obtained also by RITSEMA.

An explanation to the seismic pattern of the north-east edge of the Indo-Australian plate between the Himalaya and Hindu Kush ranges is proposed by HEUCKROTH & KARIM. It will be useful to report it here. « The original underthrusting of crustal material along the Himalayan arc, has now replaced by overthrusting into the Asian continent and the triangular seismic zone is a manifestation of this effect. In the Hindu Kush center, the apparent remanent downthrusting could well be a result of interaction of two convection cells within the mantle; one cell promoting and being associated with the movement of the NW corner of the Indian-Australian

plate and a similar but somewhat oppositely faced convection cell under the Asian continent. The interaction of these two cells could be producing the through-like pocket of seismic activity in the upper mantel below the Hindu Kush. Furthermore, as a result of these two convection cells the crustal blocks above are being pushed together with upthrusting about the Hindu Kush resulting. The north and south crustal flanks of the Hindu Kush, which correspond to the zones of shellows earthquakes (Fig. 44), are therefore a crustal manifestation of the material movements in the upper mantel ».

We substantially agree with the HEUCKOTH & KARIM model, but we suggest a variation concerning the northern convection current below the southern edge of the Asiatic plate. According to our interpretation this plate was relatively rigid and stable and suffered passively the effect of the collision of the Indo-Australian plate which moved toward north-east. Along the contact of the plates, a subduction phenomenon of the type suggested by DEWEY & BIRD (1970, p. 2642, fig. 13) came true.

The proposed solution seams more suitable to the structural pattern of the whole territory of Pamir, Hindu Kush, Karakorum and Kashmir Himalaya (DESIO, 1970) ([1]).

The inflection toward north of the tectonic axes of these mountain ranges shows a deformation produced by the northward component of the motion of the Indian-Australian plate, while the dissimetrical shape of the main tectonic lines is the effect of the eastward component and intensive compressional strengh toward the west side compared to the east side. Also the excentric position of Nanga Parbat-Haramosh massif, as regard to the symmetry axis of the orotectonic arcs, seams to confirm this opinion.

Before the collision, which tooks place in the Tertiary, the wedges of the plates, and particularly the northern one, were irregularly-shaped with projecting and receding parts. Some crust blocks divided by old deep fractures fringed the wedges of the plates.

Obviously the displacement of the blocks was controlled not only by the motion of the plates, but also by the orientation of the fractures, that is by the shape of the blocks, and by the trend of the plate margins.

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(1) The geotectonic scheme of the above mentioned area was published in 1974 during the correction of the proofs of the present volume, but it was presented in 1970. Some improvement are to be introduced in certain details, but the general scheme is still valid.

About the trend of the Asiatic wedge, we want to recall the presence of a great recess, a kind of « gulf », between the rigid Tarim platform with the Kun Lun range and the Tadhzikistan old basement to the east and west, and the Tien Shan Hercynian range to the north. The mosaic of blocks pushed toward north-east may be compared with a slab of ice, disrupted in many pieces, and drifted by a current into a gulf. As effect of the movements of the blocks, horizontal displacements (transcurrent faults), should occur on the sides, prevailingly in a south-north direction, while between them folds, reverse faults, and overthrusts should form mostly in east-westerly direction, but irregularly curved toward north. This model seams to fit the tectonic picture of the Pamir, Hindu Kush, Karakorum, Kashmir Himalaya area (Desio, 1970).

VII. NOTES ON THE PLEISTOCENE OF CENTRAL BADAKHSHAN

1. PREVIOUS KNOWLEDGE.

As already mentioned in the introductory chapter of the present volume, the Quaternary glacial deposits of Badakhshan were not known before our expedition. In particular BRÜCKL (1935) stated categorically that in the upper Kokcha basin and even in the Central Hindu Kusch no traces existed: « An keiner Stelle in mittleren Hindukush, nirgens zwischen Anjuman und Salang traf ich Spuren der Eiszeit. Rundhöcker, Moranen, gekritztes Geschiebe oder eckinger Moranenschutt sind unbekannt in diesem Teil des Hindukusch ». However, he modified his statement by adding: « Möglicherweise wurden sie aber auch durch die erosion wieder vernichtet ».

The first data concerning the presence of Quaternary glacial deposits in Badakhshan were published in 1962 by one of the present authors (A. DESIO) in a note in which the glacial deposits present in the Baharak basin, the Warduj valley and in the neighbourhood of Zebak, as well as those in the valley and in the Lake Shiwa basin were briefly described. In the same publication, moreover, were described the altered drift of a glaciation older than that of Baharak and the elevations corresponding to the snowline were tentatively determined.

The above note is one of the preliminary reports concerning the main results of DESIO's 1961 expedition to Badakhshan.

In the same year 1962, another short account on the same subjects dealt with in the previous note was published by H. SAWATA (see page 229). We will report in the following sections some data of this paper.

The geological sketch-maps have particular interest for they show some glacial deposits which were mentioned in our preliminary notes but also others. We list these deposits below:

a) Baharak moraine on the outlet of the Zardew valley;

b) moraine about 6 km upstream from the junction of the Zardew and Warduj rivers in the Warduj valley;

c) another moraine in the middle Warduj valley about 15 km upstream from the village of Sufyan (near Bashum);

d) lateral (?) moraine along the left bank of the Sanglich river, opposite the village of Zebak;

f) recent and present moraine rampart of the Qaz Deh Gol glacier and other moraines downstream (Wakhan);

g) moraine rampart in the upper Shakhawr valley (Wakhan);

h) « landslide and/or moraine » to the east of the threshold of the Shiwa lake;

i) moraines within the tributary valleys of the upper Nakhshir Par river, west of Lake Shiwa.

In the same sketch-maps many « terrace deposits » and « alluvium & land with vegetation » are marked on the main valleys of nearly the whole area explored by SAWATA.

In a preliminary publication E. GRÖTZBACH & A. VON HILLEBRANDT (1964) described the glacial deposits of south-western Badakhshan during their exploration of the Middle Khwaja Muhammad range located in the central part of the area bounded by the valleys of Farkhar and Anjuman, and the Kokcha valley. In the note are indicated, among other things, the elevations of the present snowline (4900-5000 m) and that of the most recent glaciation (3600-3700 m). The snowline of the last glaciation, considered to correspond to the Würm glaciation of the Alps, is 1300 m lower than the present snowline.

A more recent study on the present and Pleistocene glaciations in the Hindu Kush by E. GRÖTZBACH & C. RATHJENS (1969) deals with the glacial effects and the glaciation in the Varsoj, Anjuman and Koran valleys, Central Hindu Kush, as well as those of Hajigak in the Koh-i-Baba range, and in the Salang region of the western Hindu Kush. These authors present a map of the actual snowline in the mountainous area located between the eastern part of the Koh-i-Baba and the south-western limit of the Pamir. This map is partly derived from that of H. VON WISSMANN (1960) and shows the snowline to range from a maximum of 5200 m to a minimum of 4600 m. Following this there are four maps in which the glacial traces and deposits in the above mentioned valleys and the relative comments concerning the elevation of the snowline during the Pleistocene in the areas studied, were presented. This line, referred to the Würm glaciation, on the Koh-i-Baba is

indicated at 3900-4000 m (N), that is 900-100 m lower than the present day snowline on the Hindu Kush between 3500-4075 m, depending on the orientation, that is between 1025 and 1100 m lower than the present snowline.

In this study other records concerning moraines located at higher elevations and attributed to stades to which new names have been given, are also mentioned. The three authors discuss in particular a preliminately note by DESIO (1962) in which, the glacial origin of the deposits attributed by him and partially by SAWATA to moraines in the Baharak basin is refuted. This problem will be dealt with in one of the following paragraphs.

Some data on the Pleistocene and Holocene of Wakhan and the surroundings of Zebak were published by P. MIRWALD & H. ROEMER in 1967. About Wakhan the authors announce the presence of traces of one Pleistocene glaciation. Less evident are the signes of an older glaciation, while glacial deposits in the lateral valleys are interpreted as belonging to one advancement phase of the glaciers in the late Glacial time. The altitude of the snowline during this phase was estimated 1400 m lower than the present snowline for the northern orientation, that is about 4800 m a.s.l.

The authors attribute to older fluvial deposits those observed between Sarhad and Ishkashim, 200 m above the present river and the same interpretation was given to the deposits of the flate pass towards Zebak (1).

MIRWALD & ROEMER calculated also the hight of the present snowline in the northern slope of Hindu Kush facing the western Wakhan, that is 4900-5000 m and 5100 between Khandut and Babatangi.

In western Wakhan three levels of recent moraines below the present glacier ends and distant one from another 150-200 m of elevation were observed.

A glaciological study published by O. GILBERT, D. JAMESON, H. LISTER & A. PENDLINGTON (1969) deals with the regimen of two present-day glaciers tributaries of the Panjshir river which are located on the northern side of Mir Samir (5809 m) in the Central Hindu Kush. Among other things it contains the calculation of the mean altitude of the ice surface (4870 m) which would indicate the elevation of the snowline to be a little below 4900 m. If a southern orientation is taken into consideration, the elevation of the snowline would be above the summit of the mountain. Stadial moraines

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(1) This is a typical moraine rampart.

were found at 4800, 4600 and 4000 m; the highest, dated using the lichen method, appears to be only 400 years old.

Among the more recent studies concerning the Pleistocene of the area studied, there are numerous of Russian authors, not all of which will be listed here. The note by A. A. Nikonov & M. M. Pakhomov (1972) in which they describe in summary form the Pliocene and Pleistocene continental deposits around Ishkashim, Zebak and in greater detail those of Jurm, as well various Pamir localities, is of greatest importance. The spore and pollen research on a section measured in the Khash Dara gorge, 8 km NNE of Jurm, present quite new data for the palaeoclimatic interpretation of the area studied. On the basis of this study the two authors provide general conclusions which are listed below briefly.

In the valley evolution three phases of incision and three of accumulation were established as follows:

Incisional phases: Middle Pliocene, Middle Pleistocene, Late Pleistocene-Present.

Accumulation phases: Late Pliocene, Early Pleistocene, later part of the Middle Pleistocene possibly extending up to start of the Late Pleistocene.

The incisional phases are connected with uplift of the area while accumulation took place during stable periods.

In the southern Pamir and in Badakhshan there are traces of three Pleistocene glaciations, in the Early Pleistocene, another, the largest, referred to the end of the Middle Pleistocene and a minor glaciation in the Late Pleistocene. There is another one referred to the Late Pliocene, but it is only hypothetical. The presence of these glaciations are proved from morphological, stratigraphical and palynological characteristics.

As the reports mentioned above — which probably are only some of the Russian writings dealing with the same subject — were known by us during the printing of the present volume, it was possible to insert in this volume only few hints. Moreover we did not devote to this subject extensive research like the Russians, but we want to remark that some of our conclusions are confirmed by them, as we will see later on. We regret only that the reports we have had occasions to examine are not supplied with a more detailed documentation.

2. REMNANTS OF PREGLACIAL LANDSCAPE ON THE MOUNTAINS NORTH OF THE WARDUJ VALLEY.

Detailed research on the geomorphology was not undertaken in the region visited, but occasional observations were made which it is considered useful to summarize here, because they are connected with an argument to be dealt with below. It is useful, in fact, to know at least some of the features of the region prior to glaciations in order to appreciate fully the effect that the glaciers had on the morphology of the region studied.

The following are, therefore, separate notes which refer to specific areas. For this reason, they are insufficient for reconstructions to be made and still less for conclusions to be drawn applicable at all of Central Badakhshan.

The caravan route from Baharak to Lake Shiwa climbs from Furmoragh, the steep and narrow valley of Syoh Jar and reaches a pass at an altitude of 2900 m from which it is possible to see towards the north a typical plateau landscape which differs remarkably from the morphology below. Wide valleys, mountains with rounded profiles from which emerge here and there broken ridgen corresponding to outcrops of more resistant calcareous rocks. In part this rolling countryside depends on the nature of the rocks outcropping in the region around the upper Shiwa alluvial valley (black slates) although this type of morphology is not entirely due to this lithology. Proof of this is found further to the east, where the granodiorite replaces the black slates, but the morphology remains more of less the same. Also it can be added that the rock is deeply weathered and often covered with eluvial deposits; it can thus be implied that this is an old degradation surface which ranges, in this part of Badakhshan, between 3000 and 3700 m and rises gradually eastwerds to more than 4000 m. Altogerther this type of morphology indicates late maturity or old age stage on which is superimposed a very different morphology with juvenile characteristics. The major valleys, like that of Zardew, are deeply carved into this old degradation surface while towards the east, in which direction the surface gradually rises, the summits rise above 4000-4200 m and possibly represent the remains of an even older topographic surface in an advanced stage of degradation. The floors and thresholds of the cirques which often are aligned along the flanks of

the valleys, are part of the old degradation surface which has been more or less glacially modelled by the Pleistocene glaciers but also deeply eroded and dissected by the fluvial erosion, especially in the areas beyond the limits of the glaciation.

At a similar conclusion arrived also NIKONOV & PAKOMOV (1972) which stated that the upper levels of the valleys in Badakhshan are to be dated to the Upper Pliocene of Lower Pleistocene.

Together with the old topographic surfaces remaining on the plateaus in the investigated area, there are traces of another system of topographic surfaces represented by two sections of hanging valleys which are briefly described below. One is the *Khash valley* located between Naw Jurm and Rabat, and joining the middle Kokcha valley, the other is the Kalafgan valley, between Kishem and Taluqan; both of them were the sites of old lakes, as it will be seen later.

First the Khash valley is examined briefly (see fig. 48). The valley is almost 25 km long, with a mean width of its floor about 2 km and has a sinuous course with a general north-south orientation, parallel to the general strike of the bedding. The valley floor appears as an old valley bottom filled by alluvial deposits overlied by a thich bed of eolic dust between 2000 and 2200 m a.s.l. The valley is drained in two opposite directions, towards the south-east and towards the north by two small streams, tributaries of the Kokcha river, which flow into it through narrow deep gorges. The Khash river flows into the Kokcha river near Naw Jurm at 1480 m: the Rabat river flows towards the south-east and joins it near Rabat at 1300 m. The watershed between the two rivers is uncertain and occurs at about 2180 m. At the beginning of the Darrah-i-Khash gorge there is a large rocky step at 2200 m and remains of another one are still recognizable on the right hand side of the Rabat river at 2100 m; thus the old Khash valley, which slopes generally to the north, is now a hanging valley 500 m higher than the present Kokcha valley floor.

On the walls of the Rabat valley, a sequence of alluvial deposit regularly stratified is exposed. This sequence is mostly composed of grey and brown sandstone alternating with microconglomerate prevailingly composed of fragments of gneiss, granite and marble. In the upper part of the section yellow lacustrine sandy clay prevails: superiorly it grade into an eolian deposit of more recent age (loess).

At this point one is faced with the problem of the origin of the Khash valley, that is to say to which valley system did it belong. Is it an old valley abandoned by the Kokcha river?

This is one of the hypothesis which can be proposed. In this case the Kokcha river near Jurm must have turned towards the west forming a great bend in order to reach the Khash valley where, near Shahran, it must have formed another band in order to reach the present valley between Rabat and Bag-i-Mobatak. That the Kokcha river during the Pleistocene had a very sinuous course is proved by the fact that also around Faydzabad it forms a meander which cuts across hard rocks. Downstream from Faydzabad there are various remnants of orographic terraces on both sides of the valley which may belong to the same old valley.

A fragment can be distinguishextends towards Bagh-i-Shah with the just downstream from Faydzabad, ed at the top of the rocky spur which, edge at 1450-1500 m: other smaller fragments are also present on the opposite side of the valley at slightly higher elevations (1500-1600 m) and standing about 350 m above the present river. If account is taken of the fact that the valley is here covered by alluvial deposits and thus the rocky bed must be many metres below the alluvial bed, it is probably that the differences in height are comparable to those found upstream (about 500 m).

Now an other question is to be faced: belongs the old Khash valley to the system of old topographic surfaces of the plateaus mentioned above?

If we take into account the difference of altitude of the two surfaces which is about a thousend of metres, the reply seams to be negative. Nevertheless this differences can be explained by tectonic deformations of the earth surface during the Pleistocene time.

N. N. Nikonow recently published some short reports (1971, 1972), on the subject of the old valleys in our territory. According to this author the Khash valley is to be referred to an old lowered section of the Kokcha valley which, east of Faydzabad, described a large bend parallel to the present valley, but displaced to the south of it. More downstream the river flows within the Farkhar valley as far as Khanabad.

It deals with ingenious reconstructions, but up to now we lack of a sufficient documentation for to be immediatly accepted.

The Khash valley was for a certain time also the site of a lake. It was a great lake of sinuous feature, nearly 25 km long with an average width of 2 km, which filled the whole Kash depression between the villages of Dar-

rah-i-Khash and Khash. The maximum elevation of the lacustrine deposits lie about 2200 m a.s.l., but towards the north-west they are 2000 m high. The sea level must have remained at an altitude of 2200 m for a long time, for the upper limit of lacustrine deposit is found at such a height around practically the whole perimeter of the old lake.

We may now question the origin of the lake. This strange hydrographic situation suggests that the Khash valley was dammed at both ends.

It is not possible to imagine that the two outlets of the valley were obstructed by Pleistocene glaciers. We gained infact no proof that glaciers exist here as high as 2200 m a.s.l. The Khash lake could have been formed by two landslides which closed the two outlets of the valley and were later removed by erosion. There are traces of landslides on the slopes of the valley but not at the outlets. We may also suppose a recent tectonic deformation.

About the age of the Khash valley, NIKONOV & PAKHOMOV (1972) supply us with some valid data deduced from the palinological analysis of the section examined in the gorge of Khash Dara. According to the above authors the greater part of the section was deposited during the Earlier Pleistocene and was contemporary to the first Quaternary glaciation. This is the younger limit in the age of the valley: the excavation of it must be anterior, that is Pliocene.

The *Kalafghan valley*, as the preceding one, is a longitudinal valley, that is parallel to the strike of the beds, and has a disproportionate width with respect to the present discharge of the two streams which flow through it today and which run one to the east, towards the Mashad river, the other to the south-west towards the Farkhar river. The Kalafghan valley is 20 km long from the Chenar-i-Gunjeshkan pass to the Gazestan gorge and is aligned east-northeast. Near Kalafghan a third basin, in which the Bluti stream, a tributary of the Kokcha river, flows, joins the valley. In spite of being divided in three parts, the Kalafghan valley is in fact one valley with uniform characters from end to end, with a wide valley floor sloping generally to the west-southwest but with an uncertain watershed between the Bluti and Darya-i-Shor rivers at about 1700 m. The watershed is, on the other hand, well defined between the Bluti river and the stream which flows towards Kishem passing through the Chenar-i-Gunjeshkan pass at 1667 m. In the neighbourhood of the Gazestan step there are various remants of

terraced surfaces between 1500 and 1700 m which cannot be interpreted clearly. Upstream from the Gazestan gorge there are also deposits of lacustrine clay which are exposed on the walls of the Darya-i-Sor, below the village of Gazestan, about 1300 m a.s.l. It is made up of a blue and yellow-grey clay, well stratified horizontally, no less than 20 m thick. The deposit outcrops upstream for at least two kilometres and further up it disappears under recent deposits. Downstream it finishes close to the rocky spur of Gazestan, which protrudes towards the north-west from the flank of the valley.

The origin of the old lake seems to be found in the obstruction of the valley caused by an old landslide which slid down from the opposite side of the valley. The landslide is partially covered at present by a large alluvial fan deposited by the torrent which was formed in the path of the landslide.

The mountains which rise to the south of the Kalafghan valley are much higher than those to the north, rising repeatedly to more than 3000 m, while the others only reach 2100 m at one point. Furthermore, the ranges which rise to the north of the Kalafghan valley present steep faces to the south, while they slope gently towards the north, that is towards the course of the Kokcha river. Towards the north the mountain ranges are mainly composed of crystalline basement rocks (Farkhar Slate and Jalmish Tonalite), while those on the opposite side comprise the Neogene formations of the Kokcha area.

The origin of the Kalafghan valley does not appear to be the same as that of Khash, which is not a section of a valley abandoned in relatively recent times by a major river as for the previous case, but rather a depression of tectonic origin produced by the uplift of the territory to the north-west comprising the Kokcha Formation.

The region was probably drained from the south-east to the north-west, like the valley of Kishem and the region further to the east, as well as the Farkhar valley and the area to the west of it. It is probable that this drainage pattern represents the courses of the stream feeding the Neogene lake which extended into the area to the north-west as proved by the marly-arenaceous-conglomeratic deposits of the Kokcha Formation. The facies distribution provides an indication of the location of the lake (see the enclosed geological map); the coarse marginal facies (Ganda Qol and Tah Jari members)

outcrop near the south-eastern limit of the formation, while the finer clastics (marls and sandstones), deposited in deeper waters, occur further to the northwest. Later, the uplift of the area occupied by the Neogene lake produced the lacustrine sediments on which was imposed a consequent drainage pattern more or less parallel to the original one. At the same time the uplift produced the Kalafghan valley depression and the development of local drainage towards the north-east and northwest. This was, probably, the palaeogeographic development of the Kalafghan region, but it is possible that the conditions were more complex.

This interpretation does not agree with the NIKONOV's one. In a small palaeohydrographic sketch-map he includes also the Kalafghan valley in the old Khash valley system and the outlet near Taluqan.

Up to now the interpretation of NIKONOV require better proofs.

3. GLACIAL MORPHOLOGY AND GLACIAL DEPOSITS.

3.1. Introduction.

Traces were found which were almost certainly produced by Pleistocene glacial activity in various places in the area visited during the DESIO expedition in 1961 (see two previous publications 1962 and 1964). A brief description can first be made of the most significant traces. The others can be discussed later. The deposit in the Baharak basin will be left till last, since their interpretation has raised doubts and contests.

A start can be made by describing the deposits in the upper Shiwa valley [1] and the Lake Shiwa drainage basin (Fig. 31).

(1) For « upper Shiwa valley » we intend the southern branch of the Shiwa drainage system which has its head at Syah Jar pass.

3.2. Moraines of the Upper Shiwa Valley and Shakh Darra Valley.

The wide alluvial valley of the upper Shiwa river which is developed on the plateau north of the Baharak basin is dammed near its lower end, at the confluence of the Shiwa and the Shakh Darrah rivers, by a high moraine rampart elongated towards the north-west, the steepest side of which faces towards the Shakh valley (Plate IX, fig. 1). The upper Shiwa river flows in a (superimposed) gorge between the moraine and the left side of the valley. The moraine which upstream has a height of about 2750 m, descends further north to a small hill, at an elevation of 2705 m on the topographic map. Between the moraine and the Shakh river bed there are three terraces arranged « en echelon » with a difference in height of 50 m. The middle one is the most extensive and ranges in height from 2620 to 2700 m. Its surface slopes not only towards the river, but also downstream.

On the right hand side of the Shakh valley the upper terrace corresponds in height to the top of the moraine and thus represents a terraced moraine. On this side of the valley there are also remains of the middle terrace and where these are missing, they are often replaced by orographic (rocky) terraces.

The moraine is composed of a mixture rich in silt and clay with pebbles and big blocks made up principally of white granite, with which mainly quartzite and dark phyllite are associated.

The middle terrace is composed of a mixture extraordinally rich in silt showing the characteristics of glacial drift. On the other hand, the morphological features of the Shakh valley, in this area are precisely those of a glacier tongue basin, of which the moraine rampart represents a section of the border moraines. If it is assumed that the uppermost morainic terraces (the lower one is composed of fluvio-glacial deposits), extends downstream from the confluence of the Shakh and the Shiwa valleys, it must be concluded that the end of the Shakh glacier stopped downstream from the confluence. There was no opportunity to explore the lower part of the valley, but from a distance we were able to see on the right hand side of the Shiwa valley, at about 10 km from the confluence, an extended terraced area, which is clearly drawn also on the topographic map at a scale of 1:50.000. It presents the features of a glacier tongue basin, that of the Shakh glacier,

even if the position of the terminal moraine cannot be indicated precisely. In any case it cannot be very far from Qala-i-Mirza Shah Khan probably it is at an approsimate altitude of 2550 m a.s.l.

Instead, we followed the Shakh valley up to the confluence with the Nakhshir Par valley and the latter as far as the Kurang pass (3307 m) which leads to the Lake Shiwa. All along this route, glacial drift is abundant on both sides of the valley, and generally terraced in one or more systems (Plate IX, fig. 2). Up to five different levels of terraces can be distinguished, but they are generally erosion terraces and only two can be considered fairly continuous systems. These, also, gradually reduce upstream, so that in the part of the valley just below the Kotal-i-Kurang the glacial drift is very widespread at the bottom of the valley, although it remains partly hidden or mixed with debris which has fallen from the sides of the valley.

The terraced drift of the highest system climb up on the right hand side of the middle Shakh valley, where it is well developed rising to about 2850 m, that is 250 m above the present level of the river. In the middle valley, near Mantaqa-i-Syah Chagai, the lateral moraines of the lower system are at about 150 m above the present water-course and therefore about a hundred metres lower than the previous ones. It seems probable that this is a question of two different glacial expansions rather than withdrawal stages of only one glaciation. In order to confirm this it would be necessary to examine the terminal moraine in the neighbourhood of Qal'a-i-Mirza Shah, which we were unable to do.

In the geological sketch-map of the upper Shakh Darrah valley and the Lake Shiwa area enclosed in SAWATA's report, moraines are marked on the bottom of the tributary valleys of Nakhshir Par river as far as the confluence of the Shakh valley. We have seen no glacial deposits in the Nakhshir Par valley and its tributaries except those terraced above the bottom of the main valley.

Apart from this problem, that someone else may solve in future, it must be pointed out that beyond the moraine rampart at the confluence of the Shakh river with the Shiwa river at about a kilometer from it, on the left hand side of this second valley the remains of an iron stained older deposit have been identified, which seams to be a moraine. This consists of a ridge, a little over a hundred metres high, buttressed against the mountain side, and of a smaller hills situated slightly further downstream. The supposed

moraine is composed of boulder clay similar to the more recent one with big erratic blocks, some of which are of considerable size. The glacial silt is very abundant and reddish or yellowish in colour. It is suggested that this deposit, for its external position with regard to the lateral moraine, which closes the upper Shiwa valley, and for its noticeable degree of weathering may represent the remain of a glacial expansion older than that of the major embankment.

Traces of this expansion possibly should be found near the terminus of the old Shakh Darrah glacier, in the neighbourhood of Mirza Shah, an area which we did not visit.

In conclusion, at the confluence of the Shiwa and Shakh valleys there are traces of two glacial expansions; the oldest was the largest. The glacier which occupied the Shakh valley ended in the neighbourhood of Qal'-i-Mirza Shah at about 2550 m a.s.l. The upper Shiwa valley apparently was never invaded by ice: only during its largest and oldest expansion the Shakh Darrah glacier occupied about a kilometre of its length.

The reason why the upper Shiwa valley did not have any glacier of its own, during the Pleistocene, is explained by the lack, around it, of high mountains and catchment basins, although at the head of the Pila valley, one of its right hand tributaries, there are mountains more than 4000 m high. We were not even able to visit this valley and therefore we cannot say if a glacier was present there during the Pleistocene. It is sure that the upper Shiwa valley did not have any glacier upstream from the confluence with it.

In this connection it must be mentioned that the wide floor of the upper Shiwa valley is composed in the upper parts, of rather fine silty gravel (alluvial) deposit which cover a clayey gravel deposit. Near the contact beween the two deposits there is a spring line.

It is difficult to say the origin of the lower deposit. It is probable that the upper Shiwa valley was for a long time occupied by a lake dammed by a moraine, hich was gradually filled. On the slopes of the alluvial-lacustrine valley floor there are two systems of terraces which are localized at 30 m and 50 m from the valley bottom. The surface of the terraces is gently inclinated to the north, but less than the bottom of the valley, and the upper levels extends within the tributary valleys, particularly whithin the Pila valley, where is well developed on the left hand side.

Near the valley mouth, the bed of the Shiwa river is deeply incised, so

that the terraces remain hanging at a higher altitude. It is believed that these terraces also confirm the presence of an old lake and that the highest one indicates approximately the maximum height of the water level.

Before trying to determine the height of the snowline in the Shakh Darrah valley during the Glacial expansions it will be useful to examine the glacial phenomena present in the contiguous Shiwa lacustrine basin.

3.3. Lake Shiwa Area.

To the east of the Kurang pass (3307 m), which is located at the head of the Nakhshir Par valley, a wide valley starts to descend gently towards Lake Shiwa (1). The surface of Lake Shiwa is 3110 m above sea level. The lake (Plate X, fig. 1) has an irregular shape with a major arm towards the south, and a minor one to the north which are divided by a large peninsula culminating at 3760 m above sea level and separating the southern part of the valley descending from the Kurang pass. The surface of the lake is about 13 km^2, the maximum depth is more than 80 m, the length of the major arm is 9 km and its width 1 km.

The lake has five principal tributaries all of them located on its western side. Starting from the north there is the Ab Kotal draining a large glacial valley 8 km long which is dominated by ridges reaching 4700 m a.s.l. Next, to the south is the Ab Zijad, parallel to the previous one. It is 12 km long with high ridges showing typical glacial cirques. Both these streams discharge, a short distance from each other, in the northern arm (minor) of the lake. The other tributaries are at the southernmost arm of the lake. One descends from the Kotal-i-Kurang and is the shortest; another, the Baqu Bay, is 6 km long and has ridges just above 4000 m; the last is the Sangaw just over 10 km long and has ridges up to 4741 m showing glacial cirques.

A superficial outflow is missing. On the north-eastern slope below the end of the lake, at about 3000 m (about 100 m below the lewel of the lake), just above the village of Arakht, there is a group of rich springs. These

(1) According to SAWATA (1962) the local name of this lake is *Lake Shighnon*. We have not investigated on this matter. The local people know also the name Lake Shiwa; we used this one for it is marked also on the maps.

springs represent undoubtedly the subterranean outflow of the lake which passes along the contact between the country rock and the glacial till. The springs feed a small lake, the effluent of which, descends by watefalls to the Arakht valley.

According to certain texts of « Il Milione » by Marco Polo, the Lake Shiwa region was the place in which the famous Venetian traveller in 1272 improved his health which had been seriously undermined by his long travels.

The lake was visited in August 1937 by LEONARDO BONZI and E. CAGNACCI. An account of theyr visit is to be found in « Afghanistan, crocevia dell'Asia » by E. GASPANI & E. CAGNACCI (A. Vallardi, Milano 1951). The two explorers who possessed an inflatable rubber dinghy, tried to sound the depth lake, but they did not succeded as their sounding-rope was only 80 m long and could not reach the bottom.

During our visit (15-8-1961) the water temperature, measured several times, was 12° C; the air temperature in the same time was 16° C.

In the mornings the waters of the lake, of a beautiful blue, are slightly rippled by the westerly breeze. The breeze increases after midday and between 17 and 18.00 hours becomes gale force producing large waves in the lake. Near sunset the breeze stops and the water of the lake becomes quiet again. This phenomenon happens every day and was also mentioned by BONZI and CAGNACCI who experienced some difficulties during their work on the lake.

It is also worth mentioning that CAGNACCI suggested the glacial origin of the Lake Shiwa basin and noticed the presence of a moraine at the end of the lake.

As mentioned in the introduction, also H. SAWATA described the glacial phenomena of the Lake Shiwa area in a brief report of 1962, which became known to us later. This author also mentions the presence of the same moraine and a glacial landscape. On one of his geological sketch-maps (fig. 25) he put a question mark to indicate the possible presence of glaciers at the head of the large valleys to the north-west and south-east of Lake Shiwa; during our visit, however, these large valleys contained only some snow patches and the only visible glacier to the south and south-east was the Astan glacier (see page 389). A geological sketch-map of the Lake Shiwa area was published in one of our preliminary report (DESIO, PASQUARÉ & SPADEA, 1964).

The lacustrine basin is made up of predominantly gneissic rocks. The flanks are generally steep and plunge without change in inclination into the waters of the lake. The bottom configuration of the lake is not known but, taking into consideration the width of the valley and the lenght of the threshold, it can be assumed that it is also quite broad. The threshold, located on the eastern side of the lake, is in large part rocky and has « roches moutoneés ». Only on the southeastern side is there a large moraine up to 3207

m. Between the moraine and a rocky spur of the threshold 3232 m high, there is a large saddle which is about 40 m above the lake surface. The glacial till forming the southern part of the threshold (see Plate VII, fig. 2) is widely spread on the eastern side, and reaches the valley floor near Arakht at about 2700 m a.s.l. The till consists of fragments and blocks of local rocks embedded in glacial silt. The Arakht valley has a relatively wide floor and steep sides with the typical U-shape of a glacial valley (Plate X, fig. 2).

Besides the glacial till which is part of the lake threshold and which could cover an old rocky fluvial bed, there are farther to the west other two moraines, of which one, like that of the threshold, has the characteristics of a terminal moraine. It is a morainic arc, convex towards the valley, and dams it at about 3400 m. The central part of the morainic arc was eroded by the Darrah Ab-Kotal stream leaving traces of it on the left hand side of the stream. Another moraine dams the valley descending from the Kotal-i-Kurang towards Lake Shiwa at about 3300 m (see Fig. 31). However it does not appear that it is the terminal moraine of a glacier in the Kurang valley, but rather a lateral moraine belonging to the Ab Zijad glacier, the front of which probably reached lower down the valley.

The data reviewed are those collected during our short expedition to Lake Shiwa.

A reconstruction of the situation in the area during the Glacial time can now be made.

As mentioned above, the Lake Shiwa basin has the morphological features of a glacial basin, thus, at a certain time, it must have been filled with ice which reached up to the threshold and was discharging part of the morainic debris on to the lower slopes towards Arakht. At that stage presumably all the tributary valleys were occupied by glaciers converging towards the lacustrine basin. At a previous stage, during major expansions, the glacier probably reached still lower ground in the Arakht valley, however it is probable that it never reached the Panj valley (Amu Darya). The upper part of the U-shaped valley (visible from Arakht) shows a powerful modelling of the valley by the glaciers (Plate X, fig. 2), which should, therefore, have had a considerable thickness.

Another halt during the retreat of the local glaciers must have occurred after the above mentioned Shiwa phase. This is indicated by the moraine

of Darrah-i-Ab Kotal. Also the Kurang valley moraine could belong to this halt stage if it is considered that its front would be a little lower, that is within the Lake Shiwa basin, of which we do not know the bottom configuration. The different position of the Ab Zijad glacial front from that of the Ab Kotal could be explained by the fact that the latter had a large catchment basin.

The distance between the Ab Kotal moraine and the Lake Shiwa threshold is about 6 km and the difference in height about 200 m. Probably other moraines are present in the valleys nearby but there was no opportunity to visit them. The territory surrounding Lake Shiwa is affected by characteristic glacial forms. Below the Astan ridge, which will be mentioned in connection with a small present day glacier (page 389), some glacial cirques are to see on the northern and north-eastern slopes, and many more, to the south-west under the Koh-i-Shiwa (1). These glacial cirques have peaks higher than 4500 m with bases at 4000 - 4200 m and a southerly orientation; they are well represented on the 1:50.000 scale map. Cirques and glacial valleys are present also to the north-west of Lake Shiwa under the ridges at the heads of the Ab Zijad and Ab Kotal valleys. Parallel to the latter and showing cirques on both slopes are the valleys of Kedar Jak and its major left bank tributary.

In the cirques with a southerly orientation the lower parts are at about 4200-4300 m. Cirques are also found under the ridge which starts above the Kotal-i-Kurang and continues westward. The cirques occur only on the ridge which culminates at 4313 m and have their lower parts at 3600-3700 m. Other glacial cirques are present below the ridge located at the head of the major left bank tributary of the Nakhshir Par valley; also here the thresholds lay at the same height as those with a northerly orientation.

These cirques also must have possessed glaciers after the principal halt of the Shiwa phase.

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(1) Another peak with this name (4507 m) is also present at the head of the Ab Zijad valley.

3.4. Mountains between the Lake Shiwa and the Zardew Valley.

Our observations were occasional and sparse and were mainly carried out from a distance. These observations have been integrated with the data taken from the 1:50.000 scale maps and they provide a preliminary outline of the areal distribution of the old glaciers in this area, which lies just west of the upper reaches of the Panj river.

The ridge separating the Shulwadar and the Panj valleys shows a typical glacial morphology which is visible also on the topographic maps (see Fig. 46). Glacial cirques and U-shaped valleys are recognizable on both sides of the Chuk Shak ridge and presumably several contain small glaciers.

In this respect it must be remembered that this ridge, starting from the northern end of the Koh-i-Lalmi Bazgi, reaches 5141 m and then climbs to 5467 m. It never descends below 5000 m but further to the north, where it joins the Koh-i-Yaghardah which culminates at 5338 m, this ridge terminates on the Kotal-i-Yaghardah (3555 m) further north. This ridge is about 30 km long and is aligned generally north-south.

Glacial cirques and U-shaped valleys mostly face east and west, but there are some also facing north. Those facing west, judging from the heights shown on the maps, have the threshold between 4000 and 4400 m; those facing east more often 4400 m but also higher; those facing north mostly at 4000 m but also as low as 3600 m. No cirques face south.

The morphology of some groups of U-shaped valleys show the sites of old valley glaciers, for example the one which is drained by the south-western tributary of the Khush Darrah.

Glacial cirques are rarer further to the north beyond the Yagharda valley above Dasht. These cirques are mostly on the eastern slope of the Yagharda ridge culminating at 4746 m and mostly face northwards.

The glacial morphology is less evident in the Dahan Zar and Dargaw Gharib valleys but also in this area there are glacial cirques and U-shaped valleys near the heads of the valleys. Therefore, the ridge both to the north and to the south of the Kotal-i-Yarband has cirques especially on the north facing slopes. The highest peaks reach and occasionally exceed 5000 m.

Finally, the glacial morphology is also present on the ridge separating the Khush valley from the Kurkhu and Aqshira valleys, the latter ones con-

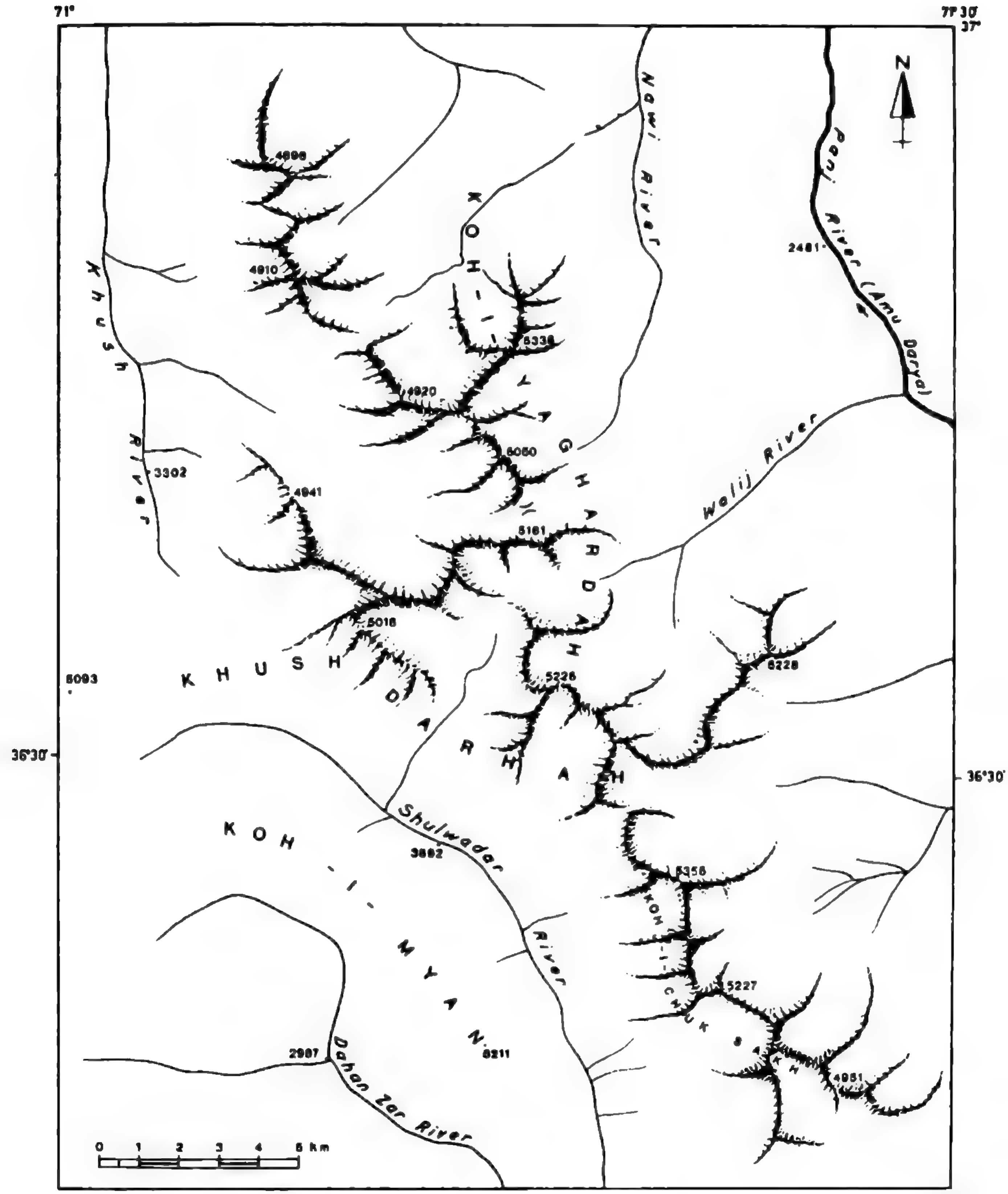

Fig. 46 - Glacial cirques on the mountain ridges between the Shulwadar and the Amu Darya rivers.

taining present day glaciers (page 387). This ridge culminating at 5093 m has glacial cirques and U-shaped valleys mainly on the eastern slope. They face generally north-east; the height of the thresholds of the cirques being between 3800 and 4000 m. It is possible that some of these cirques and valley contain actual small glaciers as is the case in the Aqshira and Kurkhu valleys.

Vast glacial deposits are also present in the upper Aqshira valley at 3100-3200 m in the small valley below the present day glacier which ends at 4040 m, that is about 900 m higher.

3.5. Zardew Valley.

The lower part of the Zardew valley is U-shaped and its confluence with the Baharak basin is dammed by an arcuate mound concave upstream and orientated north-south. This dam extends up the valley sides and its highest point is 1670 m. The Zardew river cuts through it in a narrow gorge (Plate XI, fig. 1).

Upstream from the Baharak dam there is an alluvial plain flanked by steep slopes consisting of talus. On the alluvial plain side the dam is very steep. There is a difference of 60 m between its top and the surface of the alluvial plain. Towards Baharak, on the contrary, the dam slopes gently to the west through a series of mounds more or less aligned in three rows.

The difference in height between the top of the dam and the river bed near Baharak is 150 m. That means that the floor of the alluvial plain upstream from the dam is about 90 m higher than the valley floor near Baharak. This is the result of the alluvial-lacustrine deposits which have filled the valley upstream from the dam.

From the point of view of the morphology the shape of the lower part of the Zardew valley appears to be a tongue-shaped basin abandoned by a glacier responsible for the Baharak dam.

This purely morphological interpretation is confirmed by the composition and chaotic arrangement of the materials which form the dam itself and its western continuation.

The dam is in fact composed of gravels and clays with pebbles, cobbles and blocks of white granodiorite and leucogranite; the latter generally form large mounds (Plate XI, fig. 2).

Another explanation for the presence of the Baharak dam could be that it was formed by landslide material similar to that of Ardar, located just upstream from the confluence of the Warduj valley. However, it has to be noted that the material of the dam is different from the rocks exposed on the neighbouring slopes. Furthermore, the shape of the mound and its disposition are not characteristic of a landslide.

Downstream from the dam there is another small mound and still further downstream, in the Baharak basin, there are several mounds elongated in the same direction as the Zardew valley. Pebbles of white granodiorite embedded in clay form these mounds. Those overlooking the river have steeper slopes facing it.

The Baharak dam is occasionally shown as « moraine », occasionally as « possible moraine » on the geological sketch-maps by SAWATA (1962).

Upstream from the Baharak moraine the Zardew valley is still U-shaped and presents some truncated spurs; the valley floor is relatively wide and the slopes are steep.

A large terrace consisting of gravels embedded in clay occupies the area between Malang Ab and Yarim on the right hand side of the river. It is probable that the large amount of silt in this deposit, as in others further upstream, was partly derived from glacial silt-rich waters flowing into a lake occupying the lower part of the valley upstream from the Baharak moraine. Above Yarim the mountain slopes on both sides of the river are covered by two terraced gravel deposits. One about 30-40 m above the river-bed in the lower part of the valley, but higher up the valley sides further upstream; all the villages are built on this terrace. The other terrace is present only as isolated remnants 150-200 m above the valley floor. These appear to be lateral moraines representing two glacial expansions: the lower terraces are better preserved and occasionally are parallel to the axis of the valley while the upper ones are deeply eroded and are to be referred to the « skeletal moraine » (see page 364). The deposit which occupies the highest part of the long outlier running along the right hand side of the lower course of the Kurkhu river also belongs to the highest terrace level. This deposit reaches

an altitude of 2102 m, that is 400 m above the valley floor and is also to be referred to the some moraine.

Throughout the Zardew valley there are large erratics, occasionally of gigantic size, consisting mainly of granite and granodiorite, but also of gneiss. The glacial erosion is well seen especially on the high slopes of the northern side of the valley which are mostly composed of granodiorite and gneiss.

Large fans, partly cemented, are joined to the terraces up to 150-200 m above the valley floor. Our investigations ended at the Dasht village where the Zardew river begins at the confluence of three large tributaries: the Gharsupan from the north, the Yaghardah from the south-east and the Khush from the south.

The three rivers have catchment basins in the high glacial cirques and U-shaped valleys below ridges which generally exceed 4000 m and occasionally reach 5000 m. These ridges form the watershed between the Zardew basin and the Panj valley. Some of these cirques and U-shaped valleys still contain glaciers which up to the present have not been investigated.

The part of the Zardew valley visited does not show any terminal moraines but it is possible that they exist further upstream. In addition, in the upper Kurkhu valley, below the present day glacier, the front of which is at 3900 m, the lowest moraines descent to 3200 m, that is 700 m below the present glacier front. Furthermore at 3600 m there are arcuate terminal moraines up to 50-70 m high which are composed of piles of blocks damming the valley.

These moraines are distributed « en échelon » up to the present day glacier end and represent short pauses during the retreat of the glacier. The lowest ones are partly correlatable with postglacial stages, the others were formed during historical times.

Another proof of the presence of a Pleistocene glaciers in the lower Zardew valley is provided by the large size and by the high average elevation of the catchment basin. The valley glacier must have been fed by four different ice flows. Three of them converged near the village of Dasht at 2224 m above sea level. The forth, in the Kurkhu valley, must have reached the main valley floor less than 7 km from the Baharak moraine, and at a height (true height that is without considering postglacial erosion) not very different from the elevation of the moraine itself.

3.6. Warduj Valley.

Just above Ardar, at about 5 km from the confluence of the Warduj valley in the Baharak basin, this valley is dammed by a heap of granitoid gneiss blocks mingled with abundant clay and resting on a terrace also rich in clay. This feature vaguely resembles that damming the Zardew valley near Baharak (Plate XII, fig. 1). However, here the lithology of the blocks is the same as the rocks exposed on both sides of the valley and a scar face is present on the right side above this heap. This rounded scar is the niche left on the place where the landslide fell down and therefore this feature is to the interpreted as a landslide dam. Apparently the landslide material covers a terrace the origin of which is not clear. Probably, the landslide, damming the Warduy valley, gave rise to a temporary lake which left few traces of its existence. The presence of a certain amount of silt in the landslide material could be justified by the existence of a lake and probably by its silt rich waters.

On the left hand side of the valley, just upstream from the landslide, there are terraces, more than 100 m above the landslide level, which appears to belong to the upper terrace system in the Baharak basin and which are also rich in silt. Dashtek village is sited on this terrace [1].

Further upstream the villages Tarang and Shagan are sited on other terraces on the left hand side of the valley. Another terrace about 200 m above the valley floor is located on the left hand spur of the confluence with the Aqshira valley (Fig. 47).

This same terrace continues for a short distance into the Aqshira valley also extending on its right hand side, and the village of Awji is located on it. The silt and gravel deposits forming it show distinct bedding and therefore it is assumed that it represents an old fan of the Aqshira river. Another more recent fan was formed by a river flowing in an epigenetic channel developed in the area to the right of the Aqshira confluence between the terrace and the rocky slope of the valley. The opposite terrace continues upstream, on the right hand side of the Warduj river. Below the village of

(1) The position of the village on the geological map is too high. Te Ardar dam is also shown on the sketch-maps by Sawata (1962) and is indicated with the same symbol as the « Baharak moraine » (moraine or possible moraine). A moraine is also indicated just above Sufyan.

Aqshira, there is a row of mounds which rise above the general level of the terraces near their edges, at a height of 1800 m above sea level and about 80 m above the Warduj river.

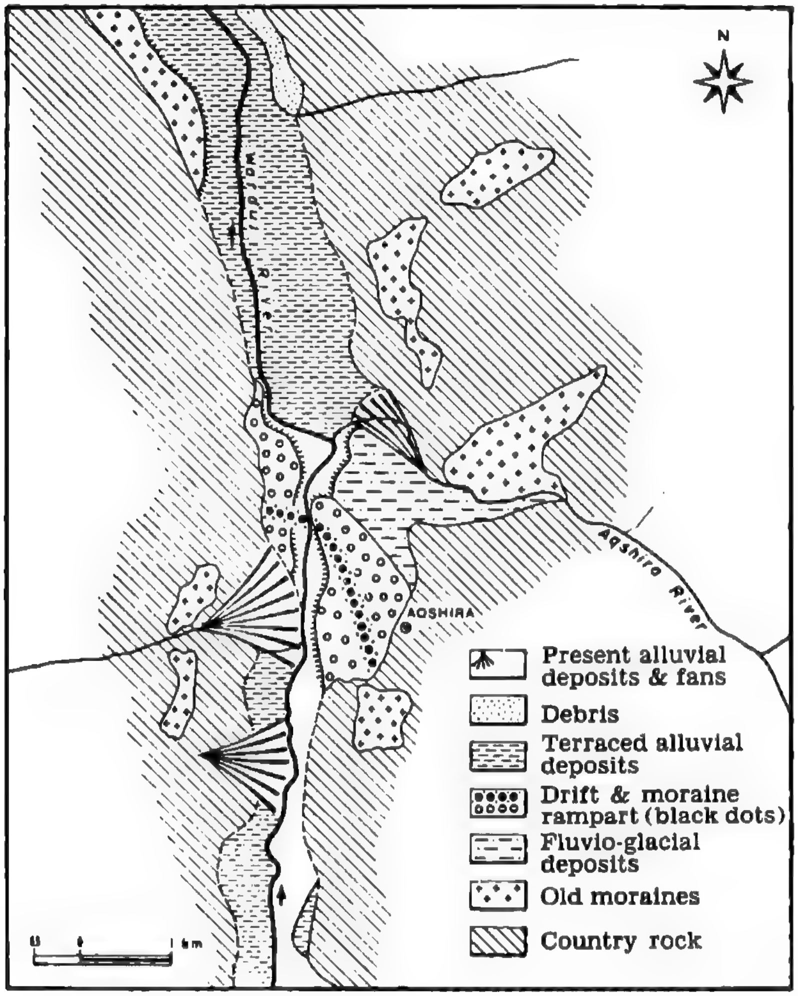

Fig. 47 - Sketch-map of Quaternary deposits of the Warduj valley near Aqshira.

These mounds project towards the Warduj river and continue on its opposite bank on another terrace remnant forming a dam-like feature oblique to the axis of the valley and cut through only by the Warduj river. This feature consists of unconsolidated material containing large blocks of migmatite easily seen in the river banks and it appears to be a glacial deposit. Assuming that it is a moraine, it is probable that it was deposited by a glacier occupying the Aqshira valley in which a glacier is present in the upper part of its northern branch (North Aqshira glacier).

Other similar deposits, more or less terraced, are present at higher altitudes on both sides of the valley: above Chakaran up to 2500 m (a little less than 800 m above the valley floor); above Awji up to 2800 m (1100 m

above the valley floor); and near Bara Bara, Khuch and Rekshan up to 2100 m (400 m above the valley floor). These deposits very probably are to be referred to moraines which belong to the largest glaciation of our territory, as we will see later.

Further upstream in the Warduj valley there is another silty gravel deposit with large migmatite blocks below Bashum village. This deposit forms a group of mounds damming its confluence with a lateral valley thus forcing the Bashum river to flow in a small epigenetic gorge opened between the deposit and the left hand side of the valley where a small fan has formed.

Both the Aqshira and Bashum deposits are similar and show the appearance of moraines. Assuming that they are glacial deposits, their origin may be due to the action of local glaciers descending from the Aqšhira and Bashum valleys in the Pleistocene, or to a glacier occupying the Warduj valley. If the source of the rocks composing both deposits were known it would be easy to decide the issue. There is little doubt that they are Pleistocene moraines because, considering the Aqshira mound, there is a glacier at present in the head of the same valley (page 387). Therefore the most probable hypothesis is that the presumed glacial deposits were laid down by glaciers descending from two lateral valleys of the Warduj.

Insufficient data are available to clarify this problem.

The feature is still more complicated near Tergeran (Fig. 35) where deposits, similar to glacial drift, are widespread, which downstream cover an orographic terrace 150 m above the Warduj river and the remnants of which are also visible further upstream; such deposits are common around Tergeran. It was not possible to establish the height that they reach in the two small valleys cutting the right hand side of the Warduj valley upstream from Tergeran village.

Above Tergeran, the Warduj valley is much narrower and the supposed glacial deposits are scarcer at least near the valley floor. Small remnants are present near Alezhgerew, near Sarask and above Abdaw. Further upstream they disappear while at the upper end of the Warduj rocky gorge (Rabat-i-Cheheltan) the valley floor widens rapidly and is filled by talus fans which occupy the lower end of the lateral valleys. The Piaw fan is particularly large and blocks the entire valley forcing the river to the opposite side.

Further upstream there are other unconsolidated deposits which belong to a different glacial basin (but not hydrographic) that is the Zebak basin which will be discussed below.

3.7. The Zebak area.

Although the Zebak valley, which originates at the confluence of the Sanglich and the Deh Gul rivers, is part of the Warduj drainage basin, it must be considered separately. This is because the glacier which occupied it during the Pleistocene did not belong to the Warduj basin, but it flowed mainly southwards towards the Panj river (see Fig. 36).

The Zebak valley has a typical U-shaped cross section with a flat and wide floor located between 2540 and 2700 a.s.l., very steep slope and truncated spurs. The through shoulders are very high (3000-3100 m) and they represent the maximum altitude attained by the glacier during the major glaciation. This assumption in confirmed by the presence of an ash-grey deposit overlying them there and there. Such deposits closely resemble, also in the type of erosion, the glacial drift which in the Karakorum valleys indicate the deposits of the oldest glaciation (« skeletal moraines »).

Also NIKONOV & PAKHOMOV (1972) referred those deposits (called « ash-grey moraines ») to the glacial drif of the penultimate glaciation, namely of the Middle Pleistocene, and we agree with them.

On the western flank of the Zebak valley, at a lower elevation (2800-2900 m), there are other terraces covered by more recent glacial deposits which could represent the altitude reached by the Zebak glacier during a less old Pleistocene glaciation.

However, near Gul Khana, on the valley floor, at about 2530 m a.s.l., there is a low moraine formed by a series of irregular mounds transverse to the axis of the valley (Plate XII fig. 2). Around this moraine rampart, especially towards the valley, there is an area with sand dunes. Upstream from it, the large alluvial plain marking the confluence between the Zebak and the Warduj valleys continues. Still further upstream, at about 8 km from the Gul Khana moraine there is a similar moraine which is much better de-

veloped near Ru Kol at 2600 m a.s.l. Between them there is a swampy plain where the course of the Warduj river becomes braided. Near the headwater the Warduj valley, which is called here the Darya-i-Waling, is still wide for about 7 km, then there follows a swampy area in which the watershed between the Warduj and the Ishkashim basins passes. The Ishkashim river is a tributary of the Panj river at an altitude of about 2820 m a.s.l. Both the Gul Khana and Ru Kol moraines should have been deposited by the Zebak glacier, the former as a left hand side lateral moraine damming the Warduj valley, the latter as a terminal moraine of the Zebak glacier. This latter glacier was fed by a high catchment basin located in the upper Sanglich valley on the northern Hindu Kush slope. This slope attains 6843 m a.s.l., in the Koh-i-Bandaka and further south-west, on the Banda Koh, reaches 6700 m.

Although the Waling valley was not visited, it must be remarked that this valley, which near Surk Darrah turns northwards, must have contained, during the Pleistocene, a big glacier which was fed by a large catchment basin. This basin is formed by three valleys dominated in their upper reaches by ridges higher than 5000 m (5467 m on the Koh-i-Chuk Shakh).

It is also possible that the Ru Kol moraine was deposited by this glacier and not by the Zebak glacier. Since the area above Ru Kol was not examined and since the lithology of this deposit is not well known, it is impossible to solve the problem. However, the observations in the field suggest that the Ru Kol moraine represents the terminal moraine of the Zebak glacier and not that of the Waling glacier.

It is opportune to recall at this point the data regarding the glacial deposits around Zebak and Ishkashim reported on SAWATA's sketch-maps (1962). In figures 20 and 27 a long moraine rampart located on the western slopes of the Zebak valley and continuing towards its northern end, is indicated; the Gul Khana moraine [1] is not shown and that of Ru Kol is indicated as « possible moraine ».

According to the sketch-maps figs. 22 and 42 the glacial deposits near Ishkashim and in particular those between this and Bazgir village are widerspread on both sides of the valley, but mostly on the south-eastern side where they reach higher altitudes.

This region is unknown to us and therefore, lacking other data, it is not pos-

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(1) The name Ghul Khana refers to a locality which on the 1:50.000 scale maps corresponds approximately to the Ru Kol moraine.

sible to establish from where the glacier which deposited such moraines came. On both sides of the principal valley there are tributary valleys which have, at their headwaters, very high ridges which must have fed the glaciers during the Pleistocene. Other glacial deposits, which occasionally reach the mouth of the principal valley, are present in various valleys of the Wakhan, which discend towards the Panj river from the Hindu Kush. SAWATA shows these on the sketch map fig. 22 which includes these areas up to the mouth of the Shakhawr valley.

The restricted amount of geological and altimetric data regarding the glacial deposits near Zebak, and between Zebak and Ishkashim does not enable a reconstruction to be made of the glacial history of the area since Pleistocene times, but on the other hand it enables one to determine that the old glaciers were very well developed near Zebak. It can also be assumed that during the phases of maximum expansion the iceflows which originated in the Zebak valley and in the tributary valleys on the Warduj side, upstream from the confluence of the two rivers, flowed together forming one glacier which descended and possibly dammed the Panj valley near Ishkashim.

Assuming that this hypothesis, suggested by the distribution of glacial deposits between Zebak and Ishkashim, is valid, it must also be assumed that the Zebak glacier had another tongue to the west, in the middle Warduj valley. It is not known where the tongue ended, but it is safe to assume that it ended to the west of the Gul Khana moraine representing a deposit which originated from a minor phase of glacial expansion, that is when the Zebak glacier ended near Ru Kol where it deposited a terminal moraine.

In order to arrive at a better understanding of the palaeogeography of this region it could be useful to reconstruct part of the palaeohydrology as suggested by the morphology of the area. The present watershed between the Warduj and Ishkashim drainage basins, the latter a tributary of the Panj (Amu Darya), runs near Sardab at 2897 m a.s.l. This watershed is poorly defined and passes through Quaternary glacial and fluvio-glacial deposits occupying a valley floor which is continuous between the two contiguous basins. The local drainage pattern shows a series of anomalies indicating recent variations in the river courses and the position of the watersheds.

As an example, the Zebak valley is orientated south-north but its principal tributary, the Sanglich valley, which joins the other (Deh Gul) just upstream from Zebak village, is orientated towards the north-east. The

continuation of the first valley is not the Warduj valley — which from Gul Khana descends towards the west and which the Zebak river reaches through a bend of 90° — but the Waling and Ishkashim valleys which join the Panj river. The hypothesis that these valleys were originally parts of the Sanglich valley, appears credible if account is taken of the fact that just above Gul Khana the Warduj river passes through a gorge having the morphological characteristics of a recent cut. Also the left hand tributary of the Warduj river, at its confluence just downstream from Zar Khan, shows a bend in its middle course; further upstream it is orientated north-northwestwards, downstream westwards. The elevation of the bend is not known. At this elevation there should be traces of the old topographic surface on which such a tributary was flowing northwards. Probably it is the pre-glacial topographic surface, traces of which were observed between 3200 and 3600 m a.s.l.

It can therefore be assumed that the watershed between the Warduj and Ishkashim basins was situated further to the west than at present, that is between Gul Khana and Safed Darrah. If account is taken of the direction of the tributaries of the Warduj between the two localities mentioned, it can be seen that they have a westerly component up to 5 km east of Gul Khana and an easterly component (Fig. 36) further to the east, and therefore it can be assumed that the watershed just passed where the change in direction occurs.

The change happened during the Glacial time when the presence of glaciers modified, through their erosive activity, the drainage pattern. The differences in altitude of the local base of erosion justify a more rapid retreat of the headwater of the Warduj valley with respect to that of Ishkashim. In the case of the former valley this level is and was represented by the elevation of the confluence of the Warduj river and the Kokcha river which now is 1354 m above sea level; in the case of the latter it is represented by the confluence of the Ishkashim river (this name refers to the stream descending towards the village from the west) and the Panj river at about 2500 m a.s.l. (1).

Although the lenght of the latter was perhaps originally shorter than the

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(1) The elevation was taken from the map of the Survey of Pakistan at 1:253.440 scale, « Zebak » sheet.

former, the difference in elevation between the confluence of the Warduj and the Kokcha and the confluence of the Ishkashim and the Panj was about 1150 m; that is, the base level of erosion of the Warduj was 1150 m lower than the base level of the Ishkashim. Also, the former, due to the structure and size of its drainage basin, contained more water than the latter.

On the light of these conclusions we may deduce also the movement of the Zebak glacier during its major expansion. Taking into account the altitude of the highest « ash-grey moraines » we can evaluate the thickness of the glacier in the Zebak valley which should have been 400-450 m; in this case one of its ice-flows should have surmounted the old watershed between the Warduj and upper Panj which at that time extended to the west of Gul Khana and invaded the upper Warduj valley.

According to Nikonov & Pakhomov (1972) during the greatest expansion of the Pleistocene glaciers the main iceflow of the Panj valley ended at about 1600-1650 m a.s.l., but a branch of it occupied the Ishkashim valley as far as Zebak and from here together with the Sanglich glacier proceeded into the Warduj valley ar far as the Baharak basin.

This situation of the old glaciers must have been anterior to that described above, as we will see later. Nevertheless, the supposed Warduj branch of the Panj glacier never riched the Baharak basin (see later).

3.8. The Baharak Basin.

The Baharak basin lies at about 25 km by road to the south-east of Faydzabad at an average latitude of 36° 55′ North and an average longitude of 70° 45′ East from Greenwich. Three rivers meet in the large basin surrounded by high mountain ranges: the upper Kokcha, which is the largest, from the south and two of its tributaries, the Zardew and the Warduj from the east, in the north-eastern part of the basin. Downstream from the confluence, the Kokcha river is restricted by high rocky cliffs thus the Baharak basin appears to be closed on all sides. The large floor of the basin, which has a roughly quadrate shape with 8 km sides, lies at an altitude of 1400-1600 m a.s.l. while the surrounding ridges reach 3700 m, although generally they are between 3200 and 3500 m. The floor of the basin consists of silt-rich gra-

vel deposits in which are embedded also blocks as large as that of white granodiorite, near the Dar-i-Hawdz bridge (Plate XIII, fig. 1). The basin floor is generally tilted (0,6%) to the north-west, that is towards the gorge and is divided in two parts by the Warduj river (Fig. 48).

The largest edge forms an elongated tongue between the Warduj and Kokcha rivers, and this tongue extends onto the rocky promotory of Dasht-i-Feraq. The other part is further to the north, on the right hand side of the Warduj river, and extends onto the northern slopes of the basin.

This system of terraces, which can be called Dasht-i-Feraq (from the village located on the larger part), is elevated from 20 to 40 m above the largest present river beds and 15-30 m above a lower level on both sides of the same rivers and consists of alluvial sandy gravels.

The Dasht-i-Feraq system ends near the entrance to the Kokcha gorge, on the north-western side of the Baharak basin and rests against the dam in the mouth of the Zardew valley mentioned on page 358.

A swarm of rounded mounds emerge from the Dasht-i-Feraq terrace surface. The largest concentration occupies the central part of the basin and they emerge above the long terraced tongue between the Warduj and Kokcha rivers, upstream from the confluence, at about 4 km from Dasht-i-Feraq village towards the north-west. Above these mounds stands a rocky hill composed of black slates about 270 m above the terrace surface (Plate XIII, fig. 2). The base of the mounds is between 1460 and 1500 m, the summits between 1543 and 1620 m.

As shown on the sketch map Fig. 48, some of the mounds are aligned in a north-westerly direction, others in different directions. An elongated ridge about 100 m high starts at the rocky hill and extends in an arcuate manner towards the south-west; another further south is lower in elevation and extends in a west-northwest direction (Plate XIV, fig. 1).

The mounds are generally composed of pebbles and cobbles of gneiss and black slates embedded in a matrix of fine-grained sands and silt. The largest blocks are mostly white granodiorite (Plate XVI, fig. 2).

Another group of mounds apparently connected with that described above, is located on the opposite side of the Warduj river, about two kilometres north of it, in front of the mouth of the Syah Jar valley.

An elongated hill extending for more than two kilometres to the northeast on the left hand slope of the Syah Jar valley rests against the mountain

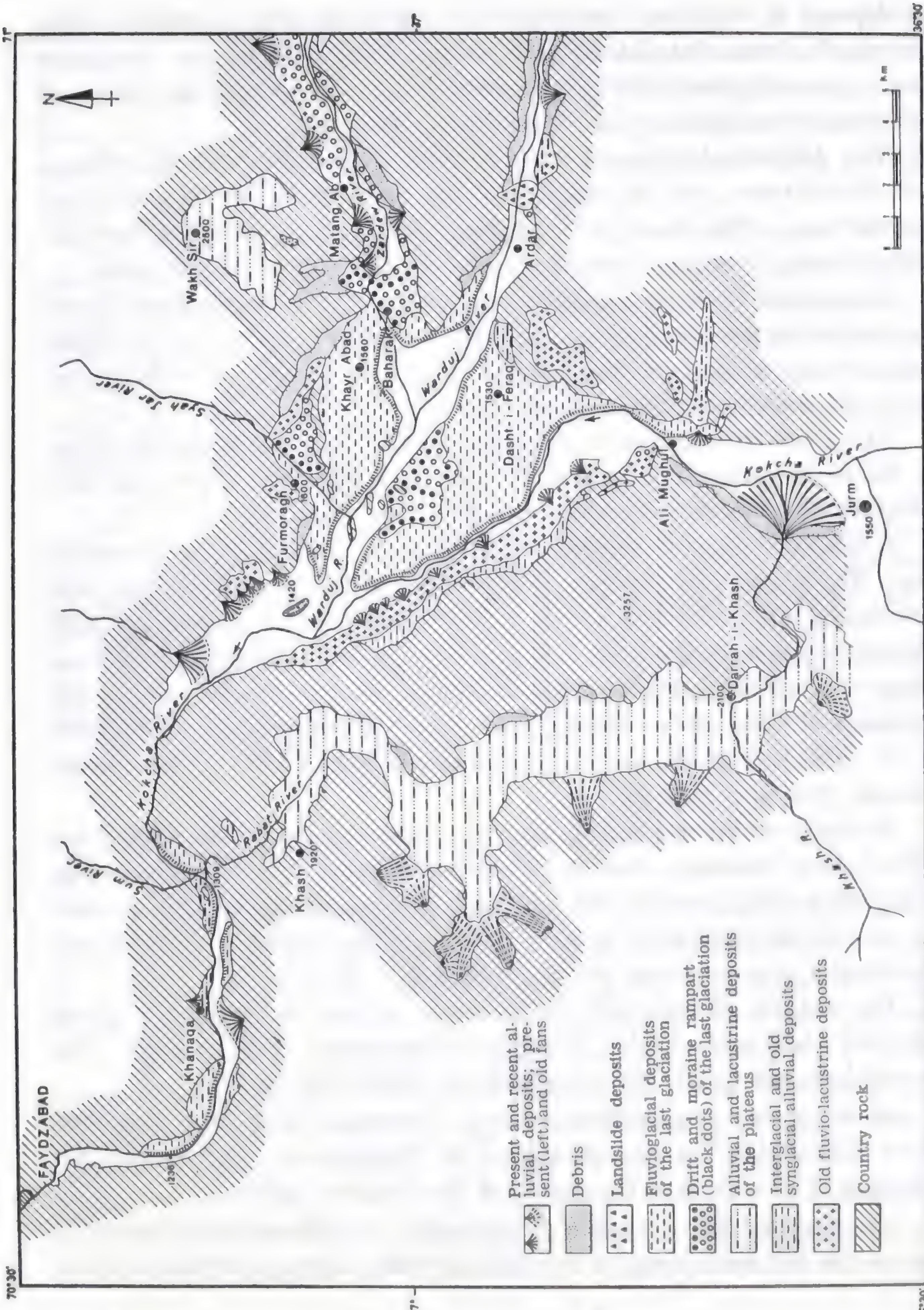

Fig. 48 - Pleistocene deposits in the Baharak area and Khash valley.

side which rises to 1600 m a.s.l., rising to the south of Furmoragh village. This hill, about 200 m above the Kol Dasht plain and 60 m above the terraced plain to the east, has an arcuate shape with the concave side to the east and surrounds a flat-bottomed basin similar to a glacial tongue basin (Plate XV, fig. 1).

The hills are mainly composed of pebbles and cobbles of grey gneiss occasionally very dark and generally zoned, embedded in a large amount of silt. The largest blocks are composed of white granodiorite.

The interpretation of these deposits will be given below.

Initially, it must be remarked that in the Baharak basin there is another terrace system higher than the one previously described, especially on the southern and western sides. These terraces cannot be correlated with the previous ones either because they have markedly different morphological and petrographical characteristics. On the slopes of the south-eastern side of the basin, between the confluence of the Jurm and Warduj valleys, on a terrace, the edge of which is at about 350-400 m above the Dasht-i-Feraq terraced plain, there is a large silt deposit with pebbles and traces of bedding in its upper part. This level, having a surface markedly tilted towards the Baharak basin, is correlatable with the large silt deposit containing pebbles and blocks. These deposits compose similar terraces on both sides of the Jurm valley mouth and those on the western side of the Baharak basin located between the Jurm valley and the entrance to the Kokcha valley, towards Faydzabad.

The petrography of the pebbles and blocks composing the terraces of the upper system, on the left hand side of the Jurm valley is notably different from that of the lower terraces. Black slates and grey gneiss are predominant and there are also epidotic rocks, quartzites, white and grey marbles, amphibolites and gabbroid rocks. A wedge of the terraced deposit preserved above a rocky terrace on the north-eastern side of the basin between Furmoragh and Khayr Abad and above Ganda Chasma village, probably belongs to the higher terrace system. The surface of this terrace ends lower down at about 1600 m and about 200 m above the valley floor.

No direct altimetric measurements were made on the wedges of the terraces in the mountains surrounding the Baharak basin, but heights were estimated in the field with the help of the 1:50.000 scale maps which are quite precise.

On the western side of the basin it appears that the terraced deposits almost reach Sar-i-Hawdz (1) at an elevation of 1800 m a.s.l. and at about 370 m above the Kokcha river. On the righ hand side of the valley mouth it appears that they reach 2000 m, almost 500 m above the course of the Kokcha. They reach the same altitude in the terrace overlooking to the south-east the Dasht-i-Feraq that is 500 m above it. The highest ones above Furmoragh seams to reach almost 1800 m on the northern side of the Baharak basin, the same altitude being reached by those on the right hand side of the Kokcha valley above the confluence with the Warduj river.

In conclusion, in the Baharak basin four distinct geomorphological elements can be recognized:

a) A lower system of alluvial terraces 5 to 10 m above the present river bed.

b) A much more extensive system of terraces, called the Dasht-i-Faraq terrace system, from 1400-1600 m a.s.l. in altitude (20-40 m above the present river bed), which is markedly tilted to the north-west, that is towards the basin outlet, consist of silt-clay-rich gravels with embedded blocks the composition of which is different from the gravels.

c) An upper extensive system which discontinuously surrounds the basin at altitudes ranging from 1600-2000 m a.s.l. and from 200-500 m above the present river beds. The terrace consists of abundant silt, bedded in the upper part, and of pebbles and some blocks of grey gneiss, black slates, epidotites (?), quartzites, marbles etc.

d) A system of rounded mounds emerging (80-120 m) above the Dasht-i-Feraq terrace surface. These are composed of pebbles of different sizes, made up of gneiss and black slates, embedded in a matrix of fine sand and silt with large blocks of white granodiorite. If the Zardew valley mouth is included in the Baharak basin area, another geomorphological element must be added:

e) The moraine rampart damming the Zardew valley near the village of Baharak, discussed on page 359.

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(1) Another village with the same name is present on the map near a bridge on the Warduj, downstream from Baharak.

3.9. Tentative Interpretation of the Pleistocene Deposits of the Baharak Basin.

Several contradictory interpretations have already been presented.

One of our interpretations suggest that glacial deposits are widely distributed not only in the tributary valleys of the basin, but also in the basin itself.

The mounds belonging to the system mentioned in d), and that of Baharak near the mouth of the Zardew valley, were presumed to have a glacial origin.

There were probably two glacial expansions in this region: during the phase of maximum expansion, the whole basin was filled with ice, which probably had a tongue reaching further downstream, towards Faydzabad. On the geological map at 1:150.000 scale enclosed with this report, the silt deposits of the terraces of the higher system previously are indicated as « old moraines » instead of fluvio-lacustrine deposits.

On the sketch maps fig. 11, 12 and 16 in the report by Sawata (1962) most of the deposits on the floor of the Baharak basin are « Pleistocene terrace deposits ». The author also added: « two steps of terraces are known in its northern margin near Farmarak and five on the southeastern margin of it ». In the same figures two moraines are indicated corresponding to the Baharak mound and the Ardar landslide heap already mentioned on pages 358 and 361.

These interpretations are refuted in a report by E. Grötzbach & C. Rathjens (1969). Both authors deny that Pleistocene glaciers could have reached Baharak basin and interpreted the mounds as fluvial erosion remains of filling deposits (talus fans) of the streams entering the basin which reached up to at least 150-200 m above the valley floor.

Another argument in favour of this interpretation is based on the height of the snowline which was determined by these authors in the Koh-i-Baba and Salang areas.

Summarily these are the negative arguments presented by the two authors cited concerning the origin of the Baharak mounds: the arguments in favour of a positive interpretation are given below.

First, the mound damming the Zardew valley in the Baharak basin is

discussed, which we (and SAWATA also) have interpreted as a moraine (Baharak moraine). According to GRÖTZBACH and RATHJENS interpretation, this mound also should be a remnant of the fluvial deposits which filled up the Baharak basin. This interpretation is refused by the following points: a) its topographic position, b) its transverse orientation to the Zardew valley, c) its profile with a steep slope facing upstream and gentle slope downstream, d) the profile of the upper reaches of the Zardew valley (which was also occupied by a lake), e) the tongue-shaped basin upstream from the dam, f) its varied lithology with the chaotic arrangement of the material and the presence of large erratics, as described previously.

It is difficult to visualize how the geomorphological agents could have produced the Baharak mound starting from an alluvial fan surface.

Both previous authors do not mention in their report this presumed moraine which being a characteristic feature and having its western spur within the Baharak basin, could be of the utmost importance in solving this problem.

If it is admitted that the Baharak mound is a moraine, the mounds which link up with this moraine and those which rise above the Dasht-i-Feraq terraced surface should have similar origin. These mounds, furthermore, do not resemble residual fan deposits since they have rounded tops, have a composition similar to the Baharak moraine and have large, scattered erratics. The same authors reported that a mound located along the road between Faydzabad and Baharak, near Sar-i-Hawdz, is composed mostly of well rounded pebbles and cobbles and angular fragments characteristic of fluvial deposits and alluvial fans. Along the same road near the above mentioned locality — which is indicated on the map acros the Zardew river, but it is not known in the area — there are however no mounds similar to those described by the two authors: up to near Baharak the road crosses the intermediate terrace system and morainic-type mounds are only present on the other side of the river or near Furmoragh and Baharak. Near Sar-i-Hawdz, as shown on the map, a large erratic of leucogranodiorite is visible and is illustrated in Plate XIII, fig. 1.

The swarm of isolated mounds rising between 100 and 200 m (not 80 m), above the principal terraced surface which occurs between the Kokcha and Warduj rivers, shows orientations not only parallel but also at right angles to the streams. These orientations are not easily explainable if the

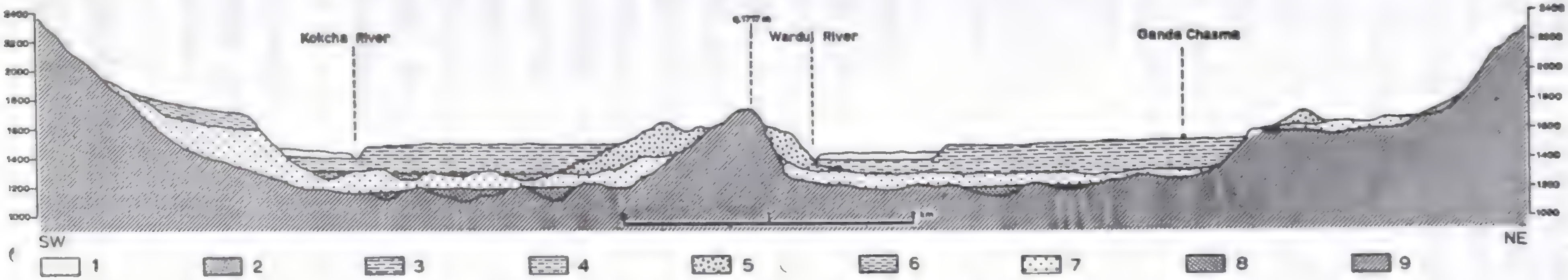

Fig. 49 - Hypothetical section across the north-west side of the Baharak basin.

1. Present alluvial deposits, 2. Débris, 3. Fluvio-glacial deposits, 4. Lacustrine deposits, 5. Drift, 6. Inter-glacial and syn-glacial deposits, 7. Old fluvio-lacustrine deposits, 8. Pre-glacial deposits, 9. Country rock.

mounds are considered to be residual deposits. These mounds also have the same composition as those of the Zardew dam. If this is a moraine, as is believed, there is no reason why a different origin should be attributed to the other mounds which are scattered on the floor of the Baharak basin.

If the mounds really represent residual alluvial deposits there is no way of explaining also the existence of the Dasht-i-Feraq terrace which should represent their base. On the contrary, the terrace of the Dasht-i-Feraq is interpreted here as fluvio-glacial deposits partly contemporaneous, partly immediately post-depositional of the Zardew moraine dam (Fig. 49).

During of maximum expansion of the Zardew glacier, the moraines outside the mouth of the valley, like those near Furmoragh and those to the north-west of Dasht-i-Feraq, were deposited, while the glacial tongue, before its final retreat, remained stationary for a fairly long time with its front corresponding to the « tongue basin » which preceded the Zardew morainic dam.

After the glacier retreated from the lower Zardew valley, the upstream basin was filled by a temporary lake which quickly disappearsed as a result of erosion of the unconsolidated barrier. A period of maximum expansion of the Zardew glacier was discussed above: however, this major glacial expansion did not necessary occur at the same time as the glaciation which produced the Zardew terminal moraine. On the contrary it appears more logical to consider that this major expansion of the glacier corresponds to a glaciation which occurred prior and was greater than that which resulted in the Zardew terminal moraine. In this respect it can be noted also that this latter moraine presents recent morphological characters in contrast to the hills scattered over the Baharak basin beyond the moraine. This interpretation is also supported by the irregularity of the Baharak basin floor which shows scattered rocky mounds and unconsolidated deposits which seams to characterize a valley floor modelled by glacial erosion.

Our interpretation provides this general picture which we now propose to alter because it does not include the presence, formerly proposed by us (1962), of large glaciers coming from the other two valleys which meet in the Baharak basin.

Apart from the glacial and fluvio-glacial deposits, we have previously mentioned a lower level of alluvial terraces obviously post-glacial, and an up-

per level, mostly composed of silt, which was represented as morainic deposits on the original edition of the geological map enclosed here.

In effect this origin of this second deposit is now refused by us. The abundance of silt and its well defined sub-horizontal bedding, at least in its upper part, suggest a deposit which is in part lacustrine. In this instance the lake was very deep. The lower edges of the terraces on the left bank of the Kokcha river, downstream from Jurm, are in fact at 1700 m and descend to 1600 m near the confluence with the Warduj.

On Koh-i-Ukaw, on the southern side of the basin, between the Kokcha and Warduj rivers, the edge of the terrace is at 1800 m and at this altitude the deposit of loose material covers an orographic terrace which rises almost to 2000 m in height.

Perhaps it is possible to correlate with this terrace system certain terraces around Furmoragh which have its edges at 1650 m and 1600 m of altitude. The surface of the terraces generally appears to be inclined towards the entrance of the Kokcha gorge, that is towards the north-west. The average dip of the surface can be estimated to be 3%.

It should be mentioned also that the lithological composition of the highest terrace system is different from that of the mounds.

It seams probably that these terraces are the remains of the infilling of the ancient temporary lake which once may have occupied the Baharak basin. No trace was found of an ancient barrier near the lower end of the basin although traces could have been removed by the subsequent erosion. It should be noted, in this respect, that there is a sudden change in the morphology at the exit from the Baharak basin, where it enters the valley of Kokcha. This latter valley has the characteristics of a river gorge of the type frequently seen where rivers drain lakes. When this hypothetical lake had its outlet in the Kokcha valley, the river bed must have been at a higher altitude than the present one, that is about 1600 m. The lower portion of the valley must have been cut by the river subsequently.

This interpretation agrees in part with that of GRÖTZBACH & RATHJENS, in the sense that they too consider that the Baharak basin was filled by alluvial materials a certain point in time. We think, however, that the infilling of the basin was only partial and, moreover, that it was largely removed before the glaciers invaded it which occupied a part of the floor leaving behing terminal morainic features.

The main points of disagreement between our interpretation and that of the two above-mentioned authors lies in our denial of a correlation between deposits of different nature and origin existing within the basin and on its margins, but above all in attributing the moraines, including the one which blocks the mouth of the Zardew valley, to residual relief produced by streams which have divided and partly destroyed the alluvial deposits infilling the basin.

The objections raised by the two authors in connection with the height of the snowline will be dealt with below in a specific paragraph.

The Dasht-i-Feraq terrace system appears to be inserted into the previous one, it must therefore be younger. Given its generally flat feature it is more difficult to reconcile it with a fluvial erosion surface than with the original surface of a fluvio-glacial deposit.

With our conclusions concerning the moraines of the Baharak basin agree in a recent report (1972) also NIKONOV & PAKHOMOV. Nevertheless these authors referred to a moraine also the deposit which dam the outlet of the Warduj valley and supposed that the Baharak basin was invaded not only by the Zardew glacier, but also by a glacier coming from the Warduj valley. We have no proofs that this event happens, but we cannot exclude that the landslide deposit overlies concealing a moraine.

3.10. Pleistocene Deposits in the Kokcha Valley downstream from Baharak.

The Pleistocene deposits along this part of the valley have been only cursorily examined for various reasons and also because only after the visit to the Baharak basin was it possible to appreciate the particular interest these deposits presented. However, even if the observations were restricted, they are considered important enough to be discussed here.

Below the confluence of the Warduj with the Kokcha, at the exit from the Baharak basin, terraced deposits were again observed on both sides of the valley, but while on the left hand side they end just below the confluence (the dip is much steeper on that side), on the right they can be traced to a point below the village of Pa-in-Sahr (1440 m) where they perhaps reach an altitude of 1650 m a.s.l.

The Pa-in-Sahr deposit can be correlated with the highest terrace system of the Baharak basin but another deposit can be seen also between Khanaqa and Rabat, on the right hand side of the Kokcha river between 1300 and 1400 m a.s.l., and perhaps it continues further downstream, near Khanaqa, more or less at the same altitude. In both cases, in a cut in a terrace, a deposit is exposed for about 50 m. This consists of unstratified gravels, reddened at the top, in which large, rounded blocks of white granodiorite are buried chaotically. Other blocks are scattered on the terrace surface, which just below the mouth of the Sum river is very extensive, but is in part covered by the talus fan of the river. This river does not have white granodiorite within its catchment area, therefore, the large blocks cannot be derived from its valley, but if anywhere, from the outcrop which is present upstream in the Kokcha valley near Abu Abdal.

On the basis of these characteristics it was though in the field that the deposit was of glacial origin (DESIO, 1962), but presently we think that it deals with fluvio-glacial materials.

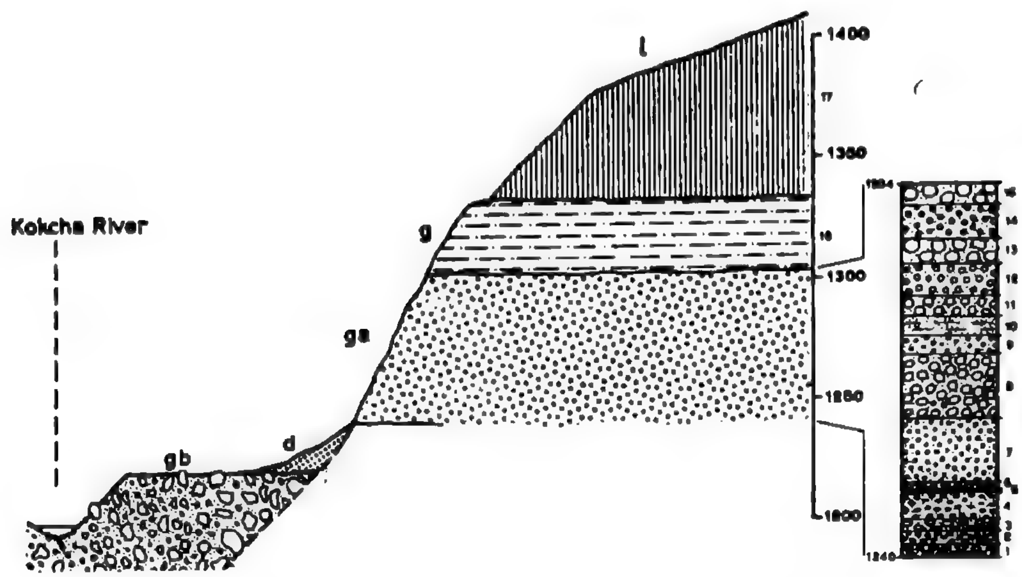

Fig. 50 - Section of the terrace opposit Faydzabad. (See in the text the explanation of the numbers).

Further downstream all the terraced gravel deposits around Faydzabad are clearly stratified, with obvious alluvial or possibly fluvio-glacial characteristics.

A section studied on the western side of the large spur of Pul-i-Kesh, opposite Faydzabad, reveals that the thickness of the ancient alluvial deposits

is at least 106 m. From the top to the base the sequence is as follows (Fig. 50):

17) Loess and eluvial deposits;
16) Sand and pebbles poorly cemented or without cement: the pebbles are slightly rounded and poorly sorted at all levels (35 m);
15) Conglomerate with large pebbles, slightly rounded, up to two metres in diameter; the pebbles are composed of white granodiorite, light coloured granitic gneiss, amphibolite, amphibole schist, amphibole gneiss and marble; the cement is grey calcite with detrital elements of feldspar, biotite, muscovite and quartz (3 m);
14) Conglomerate with 40 cm pebbles; the pebbles are slightly rounded and are similar to those in the overlying conglomerate (5 m);
13) Conglomerate similar to the bed above; the blocks are up to 2 m in diameter (4 m);
12) Conglomerate similar to the preceding bed; the pebbles are up to 50 cm in diameter (5 m);
11) Conglomerate as above, with pebbles up to 1 m in diameter (3 m);
10) Grey coarse arkosic sandstone (61 AE-18) (3 m);
9) Generally well cemented conglomerate, with pebbles and cement analogous to those of the overlying conglomerates. The pebbles are up to 20 cm in diameter (3 m);
8) Conglomerate as above, less well cemented, with pebbles up to 1 m (10 m);
7) Conglomerate as above, with rounded pebbles up to 10-15 cm in diameter (10 m);
6) Conglomerate as above with pebbles up to 40 cm (1 m);
5) Grey arkosic sandstone with pebbles up to 5-6 cm in diameter (0,30 m);
4) Conglomerate like those above, with flattened pebbles up to 20 cm on the longest side (4 m);
3) Conglomerate as above, with flattened pebbles up to 50 cm on the longest side (2 m);
2) Conglomerate as above, with flattened pebbles up to 20 cm on the longest side (2 m);
1) Conglomerate analogous (lithologically and in terms of cement) to the overlying beds; the pebbles, smooth and flattened, are up to 40 cm on the longest side (2 m);

Talus, which covers the lowest 15 m of the section, down to the Faydzabad—Kishem road (situated on the Recent alluvial deposits of the Kokcha valley). The altitude of the river bed is about 1200 m a.s.l.

The upper terrace of Pul-i-Kesh, situated 180 m above the present level of the Kokcha river, can be correlated with the highest terraces situated above the villages of Bay Malasi and Absiti, which are sited 120 m above the Kokcha river.

In the section described above it is possible to distinguish certain horizons with lithological and granulometric characteristics which are clearly different.

Apart from horizon 17 which is clearly eluvial and eolian, which will be discussed later, and the alluvial horizon 16, the interval which comprises horizons 11-15 with large blocks (up to 2 m in diameter), has similar characteristics to a fluvio-glacial deposit. A fluvial deposit is represented by horizon 9-10, while another deposit of fluvio-glacial appearance is represented by horizon 8 with blocks up to 1 m in diameter. Below, there is a deposit of fluvial type 10 m thick, while still lower in the section, ther are coarse-grained deposits alternating with fine-grained deposits of alluvial and alluvial-lacustrine types. The pebbles, as mentioned above, are distinctly flattened, like beach pebbles, the so-called « piastrell », which are formed mainly as a result of wave action. No data are available on the lower 40 m of the sequence because, as mentioned above, it is partly covered by detritus and in part by a much more recent alluvial terrace deposited against the scarp of the previous terrace.

Some comments can be made on the composition of this section which can be related to the deposits in the Baharak basin. Unfortunately, no other equally detailed sections of these latter deposits are available, therefore the correlations remain uncertain.

However, the presence must be noted above all, of horizons with large boulders (horizons 11-15 and 8) which could represent fluvio-glacial deposits. These deposits, which were traced for several kilometres downstream, will be discussed later.

Downstream from Faydzabad, near Bagh-i-Shah, the river forms a bend opposite in direction to that present near Faydzabad. Just outside Faydzabad, the valley widens rapidly and at the Bagh-i-Shah bend reaches a width of two kilometres and then, near Kuri, three kilometres. Further down-

stream, the valley becomes gradually narrower and at Halqa Jar is only half a kilometre wide; still further downstream, below Ishkashan, it narrows to a gorge at the locality where the river cuts through the Kakan Quartz-diorite. The configuration of the Kokcha valley between Baharak and Qara Kamar shows very clearly the influence that the lithology has had on its morphology. The river flows in a rocky gorge where there are outcrops of granitoid rocks or of Faydzabad Gneiss, while the valley and the river bed widen where the black slates and the Halqa Jar Amphibolite are present.

However, the lithological composition of the area alone cannot justify the width of the Kokcha bed between Faydzabad and Qara Kuzi. Downstream from Faydzabad, the river bed is infilled as shown by its low gradient (5%), the width of the river bed and the alluvial terraces on its flanks. A large terrace with a flat surface is present several metres above the present day river and contains almost in the middle of the large plain, a group of big, scattered blocks which could not be reached and therefore their origin and composition is unknown.

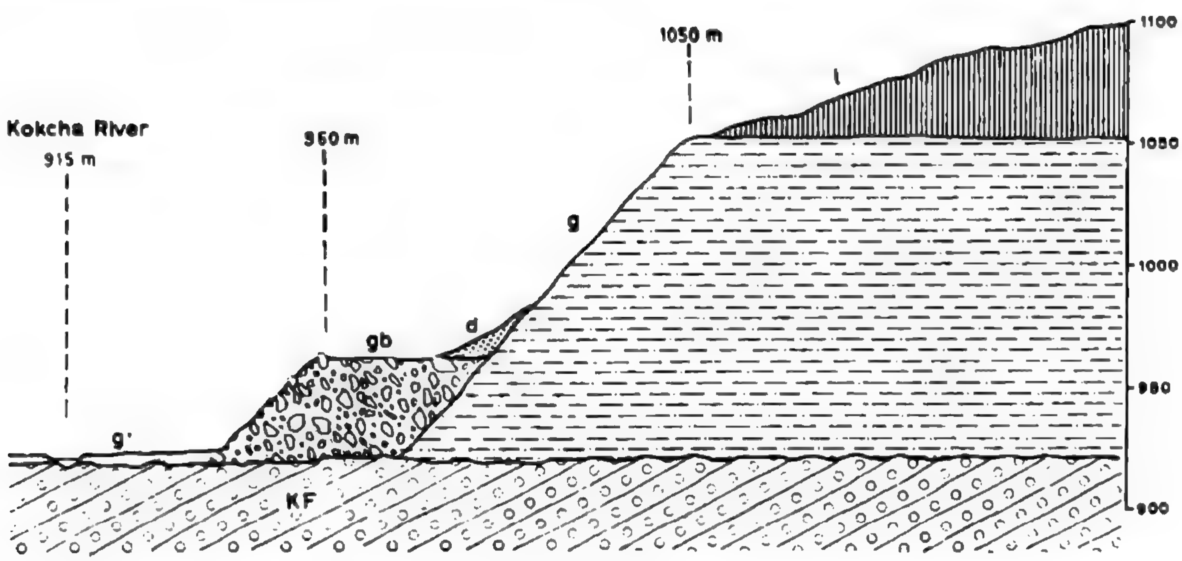

Fig. 51 - Section across the terraces of the Kokcha river near Artin Jelaw (from DESIO's field book).

KF. Conglomerate of the Kokcha Formation, g. gravel of the old alluvial deposit, gb. alluvial deposit with blocks, g. recent alluvial gravels, l. loes, d. debris.

It must be remembered also that on both sides of the valley it is possible to distinguish two systems of alluvial terraces which near Sabzi Babai, on the right side of the Kokcha river, are located at 15 and 50 m above the river; the lower system at 8 m above it. The middle and upper terrace le-

vels follow the river downstream and are occasionally replaced by orographic terraces. Their gravels are clearly bedded; they contain large blocks of granitoid rocks which give also to this deposit a characteristic aspect easily recognizable from a distance. The terrace continue downstream for several kilometres: near Artin Jelaw the three terrace levels are still well defined (Fig. 51). The lower one is only a few metres above the river bed, the middle one 45 m, and the upper one 90 m above it. All three terraces are formed by gravels, but the middle one contains more subangular large blocks the largest of which have a volume of one cubic metre. The texture of this deposit is more irregular than the others and occasionally chaotic. The gravels of the upper terrace are well rounded and generally of the size of a chicken's egg; they are mixed with large cobbles and blocks several tens of centimetres in diameter. The gravels consist of Kakan Quartz-diorite, black slate, amphibolite, white and reddish quartzite, and gneiss; the blocks are made up of Kakan Quartz-diorite. The gravels of the upper terrace are often covered by weathered material and loess up to 10 m thick.

The middle terrace is more discontinuous than the upper one because it is often covered by alluvial fans or cut by lateral streams.

The gravels of the middle and upper terraces represente the deposit with large blocks discussed previously and overlie the conglomerate of the Kokcha Formation.

The characteristics of the terraces further downstream are unknown because the Kokcha river below Dadsi was not investigated. The last remnants observed, those of Darina and Dadsi, are similar to those described previously.

The three terrace levels are well developed in the Kishem valley also. The middle one, 25-30 m above the river, and the upper one, do not invariably contain large blocks: the gravels are better sorted and consist of granite, black slate, limestone, quartzite etc. The middle level is generally covered by a light-brown or yellowish material (lehm) several metres thick.

The terraced gravels of the middle and upper levels are widespread also in the secondary valleys of the Mashad river tributaries, especially those of the western side. Special mention must be made of that descending from the Chenar-i-Gunjeskhan pass because of its extensive gravel cover capped by a deposit of eluvial clays.

Special mention must be made also of the area around Kalafghan and

mainly of the hilly region rising to the north of the village and culminating in a small peak 1866 m high. All these hills are formed by poorly bedded gravels and blocks up to half a cubic metre (Plate XV, fig. 2). The gravels consist of granite, diorite, amphibolite, black slate, fossiliferous Cretaceous limestone, and green sandstone. In the area to the west of Jeldragh only, to the north-east of Kalafghan, it is possible to see the gravels (at this location well cemented and in sub-horizontal beds) overlying the green marls and red sandstone of the Bluti and Baba Darwes formations and the conglomerate of the Kokcha Formation (Fig. 15). These gravels, which near Kalafghan have a thickness of 230 m, seem to belong to a complex much more extensive further to the west, towards Taluqan, which was significantly called *Taluqan gravels* and appear to have been derived from the Kokcha Conglomerate. However, between Kalafghan and Bluti, but near to the latter village, there are scattered gravels and blocks which occasionally are larger than one cubic metre and of various lithologies (not shown on the geological map enclosed in this volume). Their stratigraphical position with respect to the Taluqan gravels and to the Kokcha conglomerate is not always clear. This is due to the fact that apart from the blocks, the remaining part cannot be distinguished from the weathered gravels and conglomerates previously mentioned. Large blocks are present in the Kokcha conglomerate also but they are never of such a size and reach a maximum of half a cubic metre.

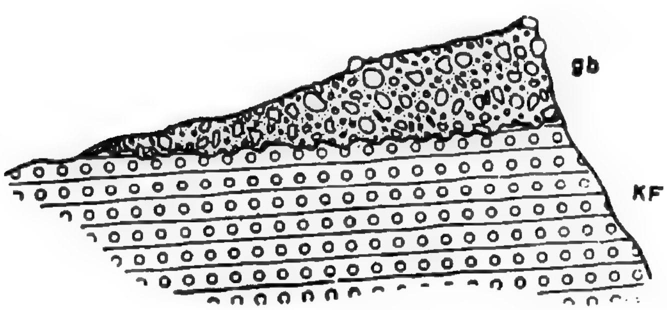

Fig. 52 - The gravel with blocks (gb) overlying the conglomerate of the Kokcha Formation (KF) near Katayan.

The presence of the blocks suggests a similarity with the gravels of the middle level terraces of the Kokcha: according to what will be discussed later, it seems that the gravels with blocks are located near the base of the Taluqan gravel.

A level with large blocks is also present in Kataghan, on the right side

of the Taluqan valley. Above the village of Khatayan the discordant contact between the conglomerates of the Kokcha Formation and the deposit of gravels with blocks is visible (Fig. 52). At this locality the gravels with blocks appear to represent the base of the Taluqan gravels which near Kalafghan also contain blocks. While visiting the region to the south of Tashkurghan, fifty kilometres to the east of Mazar-i-Sherif, at the exit from this village, a horizon of gravels with blocks up to two cubic metres was observed. The gravels are mostly formed by limestones; the blocks consist of white limestone, multicoloured conglomerate and green sandstone which outcrop in the surrounding mountains.

The gravels with blocks overlie a conglomerate horizon comparable to the Kokcha conglomerate which, in turn, unconformably overlies a horizon of brown and reddish sandstones of Eocene or/and Oligocene age (Plate XVI, fig. 1).

The stratigraphic position of the gravels with blocks at this locality also appears to be similar to that observed near Kalafghan. The presence of blocks can be explained by two simultaneous phenomena: the rapid uplift of the Bazarak Kotal range and the consequential intensive river erosion; and the increased precipitation which occurred presumably during the Glacial epoch. The gravels with blocks would thus either represent the fluvioglacial deposits of valleys the headwaters of which contained retreating Pleistocene glaciers, or fluvial deposits produced near mountain ranges during rapid uplift. The very narrow and deep gorge in limestones just upstream from Tashkurghan may be proof of this statement. The Kalafghan gravels and blocks may perhaps have the same origin.

4. THE AGE OF GLACIAL DEPOSITS IN CENTRAL BADAKHSHAN.

4.1. Introduction.

In a preceding paragraph, various deposits believed to be of glacial origin were discussed, which are present in the valleys of Central Badakhshan and a different interpretation of the Baharak basin deposits was presented.

One of the arguments suggested to negate the possibility that the Plei-

stocene glaciers could have reached the above mentioned basin of Baharak is represented by the height of the snowline during the Pleistocene glacial expansions.

It is usefud to report here the results of the investigation carried out using data which are at present available for central Badakhshan and surrounding regions.

4.2. The Present-day Snowline in Central Badakhshan.

Before dealing with the Pleistocene glacial phenomena in the area studied it is necessary to make a rapid assessement of the present glacier situation. Unfortunately, as it was stated in the introductory chapter to the present volume, detailed research on this subject was not possible and only a small part of Central Badakhshan was visited, while the higher parts of the area are to the south and to the north.

However, even the few data collected can be used to provide a brief account of the present-day glaciation; these data can be compared with those in neighbouring areas like the Hindu Kush and the Pamir which have more glaciers and are better known.

The most glaciated area of Badakhshan *sensu lato* is the northern side of the Hindu Kush because the highest ridges are in this area, the snow catchment basins are larger, and also because in this area it has a south-western orientation and represents, with its nortward facing spurs, the highest barrier to the path of the moisture bearing winds of the 4th quadrant. Moreover we have no direct knowledge of these glaciers and thus we do not intend to dwell on this matter and, in order to discuss our problem, we have used the studies of other authors.

Of particular interest to us are the glaciers which appear to be well developed in the northernmost part of Badakhshan, straddling the 38th parallel, for which however no certain data are available and large scale maps are not known to us.

The data collected refer to some small glaciers located above Zebak and in the mountainous areas of north Central Badakhshan between Lake

Shiwa and the Warduj river. Other morphological data can be derived from the topographic maps at 1:50.000 scale available to us.

Starting with the *Jagdaw glacier* located below the Jagdaw ridge, above and to the east of Zebak at 36° 31′ north. The ridge is generally aligned north-south and two peaks dominate the small glacier, one at 5081 m and the other at 4992 m. It is a small glacier occupying the upper part of a cirque which is wide in the lower parts and ends at about 4520 m above a detrital slope. The glacier, facing east-northeast, has a sub-triangular outline with one side parallel to the ridge and a rounded front. The total area is about 3,77 ha. This small glacier provides an opportunity to determine the altitude of the snowline.

An attempt can be made to obtain the average height of the glacier surface using Kurowski's method; the height must fall between 4500 and 5081 m which are the lowest and highest elevations of the glacier. If account is taken of the sub-triangular shape of the glacier having an apex at the lower and, it is possible to determine the mean height of the surface at 4830 m, which can correspond with the altitude of the snowline. The other examined glaciers are located on the western side of the Koh-i-Khush between two through valleys and a cirque which open into the upper parts of the Kurkhu valley and the northern tributary of the Aqshira river. Their mean latitude is 36' 51′ North.

The *North Aqshira glacier* is situated at the bottom of a large valley, generally facing west-northwest, below a ridge which culminates in two peaks 4917 and 9421 m high (1) (Fig. 53). This glacier has a sub-trinagular shape elongated towards the lower end with the shortest side parallel to the above mentioned ridge. It is about two kilometres long, has a mean width of 700 m and an area of about 11,60 ha. In August 1961 the highest point of the glacier was at 4917 m, the lowest at about 4080 m. The glacier has a well shaped catchment basin with two unequal ice flows and a sort of rather large tongue which starts at about 4350 m, but which in the lower part is mixed with detrital material and disappears under it probably extending towards lower levels with dead ice and detrital masses.

The average maximum and minimum height of the glacier is about 4500

(1) The data concerning the Aqshira and Kurkhu glaciers were collected by G. Pasquaré during Desio's 1961 expedition.

m, the average height of the surface is slightly less and is 4450 m. This height could also represent the altitude of the snowline.

Another small glacier is located within the adjacent cirque to the south of the preceding one. We called it *South Aqshira glacier* but we renounce to include it in our calculation for the lack of data.

At the head of the Kurkhu valley there are two glaciers, the larger, in the valley, is called here the Kurkhu glacier and the one in the cirque is called here the North Kurkhu glacier.

The *Kurkhu glacier* is in a narrow deep valley prevailingly facing north, which descends from the ridge culminating at 4863 m. On both sides of the catchment basin of the glacier there are another two peaks which reach 4773 and 4621 m. The glacier has a single catchment basin, is sub-rectangular in shape, about 3 km long, and a relatively uniform width of 700 m.

Fig. 53 - The glaciers of the upper Kurkhu valley (to the north) and the northern branch of the Aqshira valley. From a sketch-map of August 1961 by G. PASQUARÉ. Scale 1:100.000.

The surface of the glacier, in the middle and lower parts, is covered on both side by lateral moraines which, lower down, join together completely covering the surface of the ice which probably continues in depth as blocks of dead ice. The highest and lowest points of the glacier in 1961 were respectively 4600 and 3900 m; the area was 14,55 ha; the mean height of the

surface of the glacier is slightly higher than the average of the maximum and the minimum heights of the glacier (4250 m) and was about 4240 m. This figure can be considered as the snowline for a glacier of middle size having a northerly exposure.

The *North Kurkhu glacier* is a small glacier occupying only part of a cirque located on the western side of the peak marked 4835 m on the map and which ends above a rocky step overlooking the right hand side of the previous glacier. When the North Kurkhu glacier was more extensive it must have formed a lateral hanging tributary of the Kurkhu glacier. At present the glacier is completely indipendent and possesses a terminal moraine. The North Kurkhu glacier has a more or less sub-quadrangular shape with an apex near the highest point at about 4600 m and another at the lowest point around 4280 m. It has an area of 2.80 ha. The average of the highest and lowest points is 4440 m and the mean height of the surface of the glacier is slightly less, about 4400 m. This height, which can be considered to correspond to the snowline for glaciers with a westerly orientation, almost coincides with that found for the North Aqshira glacier exposed to the north-west. Another glacier, for which some data are available, is the *Astan glacier* located 9 km south of Lake Shiwa. The Astan glacier lies on the northern side of the Koh-i-Astan generally aligned north-east and culminating at a peak 4756 m high. The glacier lies at an average latitude of 37° 18′ north and occupies the upper part of a small valley which descends towards the north and immediately below the highest part of the Koh-i-Astan ridge, between the peaks marked 4756 and 4765 m. The glacier is tributary of the Jog Beg Qamar, one branch of the Arakht river. The glacier has an irregular shape and is divided in two parts by an arete belonging to the same ridge. It has an area of about 8 ha and ends lower down with an irregular front at about 4200 m (1). The average height of the surface has been estimated to the be at about 4420 m. These data, although uncertain, have been presented for lack of better information, in order to indicate approximately the height of the snowline in that area. This limit does not differ remarkably from 4420 m for a glacier having a northerly orientation.

The Astan glacier is marked in a sketch-map of Sawata (1962, fig. 25). In the same fig. 25 four other small glaciers are mared 5-6 km to the east, but in the

(1) This extimate was made from a distance.

1:50.000 maps no high ridges are to see in this area. Other eight small glaciers are (doubtfully) marked in the fig. 25, at the head of the Ab Zijad and Ab Kotal valleys. We have seen no glaciers in these valleys.

At this point an attempt will be made to obtain data about the present-day snowline which could serve to compare the data that we shall try to obtain about the traces of the Pleistocene glaciers of the region studied.

As is well known, the methods in use to obtain the height of the snowline from altimetric and morphometric data of glaciers, are many and it is not considered necessary to report them here. On other occasions (Desio, 1936) Kurowski's method (1891) was used in the Karakorum range with success both for large and small glaciers; the same method has also been used for Pleistocene glaciers in an Alps [1] with statisfactory results.

When there are no detailed topographic maps and, above all, they lack contour lines, the Höfer method (1879) with some amendments can be substituted for the previous one; this method has been widely used for Pleistocene glaciers when it was not possible to reconstruct their surfaces. Both methods give equal or very similar results when the surface of the glacier is uniformly sloping and its shape is similar to a square or rectangle which often occurs in small glaciers.

After this brief introduction it is reasonable to summarize the data obtained up to now in order to determine whether they agree with each other and with those of the neighbouring region, and how the present-day snowline in the region studied is distributed. In the table of the page 391 the data relative to the various glaciers studied are summarized; the glaciers are listed according to their latitude.

As far as the snowline in the three areas where the above mentioned five glaciers are present is concerned, the Kurowski and Höfer methods could be used in the computations, the first because it is reputed to be the most exact, the second because it was used for the Pamir glaciers and for some glaciers studied in the Hindu Kush, with which the values obtained for our glaciers will have to be compared.

Now we must modify the data relative to the orographic snowline with the so called *orographic coefficient* which represents the number of metres by which the average height of the glaciers is above or below the climatic

(1) A. Desio (1927), *L'evoluzione morfologica del bacino della Fella in Friuli.* « Atti Soc. Ital. Scienze Nat. », vol. XLV (1926), p. 397, Milano.

graphical caracteristics of some glaciers in Central Badakhshan.

...e	a Basin	b Lat. N	c Orien-tation	d Length km	e Height of glacier end m	f Area hectares	g High of the highest peak m	h Average high of the highest crest m	i Average high of the highest crest and glacier end (Höfer) m	l Average high of glacier surface (Kurowsky) m	m Differe... i-l m
...cier	Warduj	36°31′	ENE	1,5	4520	3,77	5081	4995	4758	4830	— 7...
...a	Warduj	36°51′	WNW	2	4080	11,60	4921	4720	4400	4450	— 5...
...er	Zardew	36°52′	N	3,0	3900	14,55	4863	4680	4290	4240	+ 5...
...u	Zardew	36°52′	W	0,75	4280	2,80	4835	4725	4502	4400	+ 10...
...	Arakht	37°18′	N	0,75	4200	8,00	4756	4750	4488	4420	+ 6...

snowline and is due to such factors as the orientation, the shape of the glacier basin, the avalanche alimentation, the insolation etc.

This coefficient is very important not only for defining the present-day snowline, but also for correctly interpreting the moraines left by previous glaciations and during the retreat of the Pleistocene glaciers.

It must be noted here that at least part of the criteria used for the determination of the orographic coefficient is rather subjective and as a result of this the extimates considered by various authors do not agree.

The only factor of the coefficient which can be objectively determined, is represented by the orientation, which theoretically is deduced from the insolation without taking into consideration the cloud coverage and the other local factors such as the slope of the glacier surface, the shadowing, the type of alimentation etc. This factor can be calculated with precision for all latitudes ([1]). It is obvious that the northerly orientation produces a lowering of the snowline, while the southerly orientation produces a rise. The arithmetic mean of the two values should provide the height of the snowline but the other factors significantly modify the resulting value. The easterly and westerly orientation apparently should not influence the height of the snowline but, also in this case, account should be taken of the factors and in particular the direction of the rain bearing winds. However, only when the data concerning all the factors are accountable, it is possible to obtain with the arithmetic mean, the most accurate values of the height of the snowline. Also in this case the local factors must be considered.

In our case it must not be forgotten that the available data are so restricted (only five glaciers of which three are located in a small area were examined) that the corrections adopted by other authors in neighbouring areas must be considered, in order to correct the orographic values.

The Jaghdaw glacier, which is located further to the south and is nearest to the Hindu Kush range, will be examined first.

The values obtained using both methods differ greatly (—72 m with the Kurowski method) but not sufficiently to invalidate that obtained by the Höfer method which although approximate for defect, must be borne in mind in order to compare it with those obtained by other authors in neighbouring areas. When account is taken of the east-northeasterly orienta-

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See A. Desio (1967), p. 738.

tion of the glacier only the average elevation of its surface has to be modified in order to obtain the height of the snowline.

The height of 4900 m could represent the altitude of the snowline if account is taken of the northerly component of the orientation. The fact that the Jaghdaw ridge, further to the north, does not reach 5000 m and that glaciers are absent on the east side, in the western cirques, as well as in those facing north, demonstrates that the 4900 m figure must not be far from the truth.

Consideration must now be given to those glaciers in the Koh-i-Kush region. The average height of their surfaces are 4450, 4240, 4400 m for orientation ranging from west-northwest, north and west respectively. If an analysis is made of the Kurkhu glacier, which is the largest and faces north, in order to obtain the height of the snowline the mean height obtained must be increased by about 300 m to take account of the orientation (selecting a value slightly higher than that of Zabirov for the closest area of the Pamir (see page 395). Thus the snowline has been computed at 4540 m which can be rounded up to 4600 m. The increment for a westerly orientation (North Kurkhu glacier) would then be 200 m, for a west-northwesterly orientation (North Aqshira glacier) 150 m. The difference between these two values can be attributed to the morphological coefficient if consideration is taken of the fact that the first is a small cirque glacier while the second, although of modest dimensions, is at least five times larger and shows the characteristics of a valley glacier with morphological affinities to the Kurkhu glacier.

If the average of the values obtained for the three glaciers using the Kurowski method is calculated, a value of 4363 m is obtained. This value also should be significantly increased to account of the fact that glaciers with southerly and easterly orientation are not present and the values are missing from the calculation. In order to arrive at the figure of 4600 m the increase is of the order of 237 m, which value appears to be reasonable if consideration is also taken of partial alimentation by avalanches, so that 4600 m can be considered justifiable (1). If reference is made to the val-

(1) The factor of the avalanche alimentation, to which some authors attach great importance for the calculation of the orographic coefficient, is proportional to the steepness and extent of the rocky walls overlooking the glacier. Such characteristics, which in Hindu Kush, but mainly in the Karakorum are very important, in the case of the glaciers studied, do not exceed those of the second order glaciers in the Alps (Desio, 1967).

ues calculated with HÖFER method for the Kurkhu glacier a height of 4690 m is obtained, which is 90 m higher than the previous value.

In order to make our data comparable with those found by ZABIROV in Pamir using the HÖFER method, the previous value must be increased to 4700 m with an excess difference in value of almost 100 m.

The Astan glacier, the last to be discussed, has a mean surface height of 4420 m for its northerly orientation. For the same glacier the height of the snowline would be 4700 m, that is an altitude significantly higher than that of the Koh-i-Khush glaciers which are 53 km in a straight-line to the south-southwest. However, as stated above, the topographic data relative to these small glaciers are at least in part doubtful and consequently are of no great importance in the general picture. If the HÖFER method is used, we obtain a slightly higher figure as in the previous case.

Some comments must be made in connection with the figures presented above. The values which appear to be most reliable are those which relate to the Koh-i-Khush because they refer to three glaciers rather than to only one, as in the two previous cases, and also because their heights are more accurately determined. If the values relative to the Jahdaw and Astan glaciers, situated one further to the north and the other further to the south, are accepted as valid, it must be concluded that the snowline rises towards the south, that is towards the Hindu Kush range, and also towards the north, that is towards the highest parts of Northern Badakhshan.

At this point it is useful to compare our data with those which concern the closest mountainous areas which are the Hindu Kush, to the south, and the Pamir to the east.

Regarding the first, we have at our disposal the data provided by A. v. WISSMANN (1960), more recent data by E. GRÖTZBACH & HILLEBRANDT (1964) relative, however, to a part of the above mentioned range that is the Khwaja Muhammad group and finally those of E. GRÖTZBACH & C. RATHJENS (1969). WISSMANN's data refer, above all, to the glaciers on the southern side of the range with figures ranging from 4700 to 5200 m for the orographic limit taking into account the fact that the lower figures refer to the northern side of the chain. On the Khwaja Muhammad group the two above mentioned authors obtained an altitude of 4700 m for a northerly orientation and up to 5200 m for a southerly one. The values for the climatic snowline were found to be 4900 and 5000 m. In these calculations

the orographic coefficient adopted must be take into account. Generally, according to WISSMANN's figures (p. 49), in subtropical regions with low precipitation the difference between the northerly and southerly orientation amounts on average to about 400 m, while it is about 200 m in the highest rainfall areas of the northern hemisphere.

GRÖTZBACH & RATHJENS (1969) indicate an average value between 300 and 400 m for the Khwaja Muhammad and the Koh-i-Bandaka mountains. In the same report a sketch-map with contour snowlines of Hindu Kush, between Koh-i-Baba and Tirich Mir, is enclosed. This sketch-map, which was partially deduced from WISSMAN's map, shows an area of maximum elevation of the snowline (5200 m) within the upper Kokcha drainage basin.

Westward the contour snowlines lower along the Hindu Kush ridge to a minimum of 4800 m (to the north of Jabal-us-Siraj) and then they rise as high as 5100 m on the eastern ridge of Koh-i-Baba. In the middle Jurm valley the contour snowlines run very close to each other, and near the Jurm village they become as low as 4600 m. Further north-east, that is in direction of south-west Pamir, the contour lines spread out once again.

The use of HÖFER method, also with slight corrections, is doubtful. However these are the most reliable data available for that area. These were the data used by the two authors for their map of the isochiones which for the part nearest to the area considered by us, are dotted because they were taken from WISSMANN's map which deals with the whole of Asia.

The altitude of the snowline derived from the Jaghdaw glacier was calculated as 4900 m (page 387). We are therefore in agreement with the data determined by GRÖTZBACH & HILLEBRANDT.

The Pamir, concerning which there is an important work by R. D. ZABIROV (1955), the essential data of which were also mentioned by WISSMANN (1960) (1), is now to be discussed.

A start can be made by referring to the Shugnan range, situated in South-west Pamir, which has glaciers and is nearest to the Lake Shiwa area and the Astan glacier. According to ZABIROV's data, reported by WISSMANN (1960, p. 1193), the north-western side of the range has three glaciers, all oriented to the north, like the Astan glacier. The determination of the oro-

(1) We have used WISSMAN's data because the original was not available to us.

graphic snowline appears to be certain (4400 m) for only one, whereas for the other two the estimated altitude is doubtful; however it is 4350 m and 4320 m. The height of the snowline for this area is estimated at 4600 m. An increase of 243 m is used to counterbalance the northerly orientation of the three glaciers.

Reference is now made to the Astan glacier calculated with the Höfer method — in order to follow closely Zabirov's determinations — is 4488 m. This value is slightly higher than that of the three glaciers under discussion (the mean height for these is 4457 m). In spite of the uncertainties concerning not only the data for the Astan glacier, but also at least two of the three Pamir glaciers, we consider the high of the snowline 4600-4700 m to be sufficiently accurate, for both the south-western part of the Shugnan range and the mountainous region of the Astan glacier.

The small group of glaciers in the Koh-i-Khuch area are now to be considered. The Pamir mountain range, nearest to the above mentioned glaciers, is the Ishkashim range, which also has glaciers. The data concerning the height of the snowline are derived in particular from six glaciers and vary between 4650 m and 5000 m, but in this case also some data are doubtful. Wissmann limits himself to stating that the height of the snowline is lower than 5000 m. Referring to the values of the height of the snowline in the Koh-i-Khush, previously determined, a height is obtained slightly lower than the lowest value (doubtful) indicated for the Ishkashim range. If, however, reference should be made to the Shakh Darrah range, which is further east, yet higher values would be obtained, and this suggests a raising of the snowline in that direction. This hypothesis is confirmed by the further increase in height of the snowline in the mountainous areas, which is situated further to the east.

A more general consideration can now be made of the position of the snowline in Central Badakhshan and reference can be made to Wissmann's map (1960), because Grötzbach & Rathjens have prepared their map (1969) using Wissmann's that is for the part which is of direct interest to us.

The 4600 m contour line, which passes just to the south of Lake Shiwa, coincides with the height indicated above for the Astan glacier, but the uncertainty of this value has already been discussed. In the Koh-i-Khush mountain region the snowline lies between the 4600 m and 4800 m contour

lines on WISSMANN's map. The mean value obtained by us is 4600 m, which corresponds to that of the lower altitude contour line, whereas, on WISSMANN's map, the line nearest to the Koh-i-Khush should be the 4700 m line.

Reference should really be made to the average of the figures obtained with the HÖFER method, which has been used for the Pamir. Then a slighly higher mean value would be obtained, that is 4634 m, taking into consideration the corrections relative to the orientation. This is still a lower value than the one appearing on WISSMANN's map.

It can be asked whether further corrections to our data are necessary, or whether corrections should be made to the orientation of the lines in Central Badakhshan on WISSMANN's map, since his lines in the area under consideration are dotted, and thus uncertain. We think that the direction of the 4600 m a line should be corrected. It should be moved slightly further to the east, where is a dotted line, so that it is aligned closer to a north-south direction, like the 4800 m line, to which it would be more or less parallel. The same should be done for the 4400 m line.

If this slight correction is made, then the Koh-i-Khush area would lie between the 4600 m and 4700 m contour lines (interpolated). This agrees with the glaciological data we collected in that area.

According to a report of M. G. GROSVAL'D & V. M. KOTLYAKOV (1969) the hight of the equilibrium line of the present glaciers in Alay and Pamir lay between 3800 and 5200 m.

5. THE ALTITUDE OF THE SNOWLINE DURING GLACIAL EPOCH IN CENTRAL BADAKHSHAN.

The age of the deposits believed by us to be glacial in this area can be deduced from the difference between the old snowline and that of the present.

In the previous chapter we have attempted to determine the altitude of the snowline for five present-day glaciers, the morphological data of which are available. In the table 5 at page 391 the values obtained with the KUROWSKI and HÖFER methods are shown. Regarding the Pleistocene

glaciers, the first of the two methods cannot be applied because there are not enough data available to reconstruct cartographically the surface of the glaciers. It is therefore necessary to use the HÖFER method which moreover has also been used in Pamir.

The Baharak moraine which, as it is known, dams the *Zardew valley* will be discussed first. In the Zardew drainage basin the present day glaciers which are probably present, were not investigated. Some data however are available which concern present-day glaciers occurring under ridges very near to those above the Zardew basin. These are the Aqshira glaciers, the Kurkhu glaciers and the Astan glacier. The Jaghdaw glacier, in the Zebak area, cannot be taken into consideration because it is very far away and near the Hindu Kush range.

In order to compare the data, the values obtained for the four glaciers must be converted using the HÖFER method. These data are 4400, 4290, 4502, 4488 m respectively and refer to glaciers facing west-northwest, north, west and north. The average is 4420 m. It is difficult to establish which corrections should be employed. The northerly component of two of the glaciers could increase this value slightly. However, if the orientation of the Pleistocene glaciers, with which the present day glaciers are to be compared, were the same or slightly different, there would be no need to introduce any corrections.

The first comparison will be with the Zardew glacier at the time when its front was near the Baharak moraine (1670 m). This glacier was generally facing west and therefore the best comparison should be with the North Kurkhu glacier, which is facing in the same direction and with the North Aqshira glacier which has also a prevalent westerly orientation. The average values for the two glaciers is 4450 m which appears to be the best approximation.

If an attempt is made to determine the height of the snowline for the Zardew glacier with the HÖFER method and if the average height of 4600 m is considered for the ridge of the catchment basin, a value of 3135 m is obtained. The lowering of the snowline with respect to the present day values would therefore be about 1200 m. Now an attempt will be made to determine the hight of the snowline for the other glaciers of which traces were observed.

Regarding the Shakh Darra glacier no certain altimetric data are availa-

ble for its end, which was estimated to be at about 2600 m and consequently the values which are obtainable are rather hypothetical. However, the average height of the ridges of the catchment basin can be estimated to be at 4300 m. The average is 3450 m. A present day glacier lies near the catchment basin, that is the Astan glacier for which an average height of 4488 m was calculated with the Höfer method. This value, however, refers to a northerly orientation and for a westerly orientation should be raised to at least 4550 m. The difference is 1100 m and this value should correspond to the lowering of the snowline with respect to the present altitude: as said above this value is very uncertain.

The *Lake Shiwa glacier* will now be considered. The glacier occupying this lacustrine basin was fed by two iceflows coming from north-west and south-west respectively. The average height of the ridges of the catchment basin is about 4500 m, the height of the moraine on the edge of the lake is 3200 m and therefore an average value of 3850 m is obtained. This value can be compared ith that obtained for the Astan glacier which is 4488 m and is related to its northerly orientation, while the orientation of the Lake Shiwa glacier can on average be considered to be easterly and therefore must be increased to 4530 m. The difference of the snowline values is 680 m, which represent the lowering of the snowline in relation to the Lake Shiwa moraine.

The *Zebak glacier* will now be considered which is located further to the south than the previous ones and is fed by a catchment basin on the northern side of the Hindu Kush (Fig. 54).

Considering the position of the Gul Khana and Ru Kol moraines it can be assumed that the Zebak glacier front halted at a height of about 2565 m a.s.l. (average of the elevations of the two moraines). The average height of the ridges of the catchment basin can be estimated at about 6000 m. The average of these two values is 4141 m., which applies to a northerly orientation. If a comparison is to be made with the value obtained for the Jaghdaw glacier, facing east-northeast, it should be increased to 4200 m.

The lowering of the snowline represented by the Gul Khana and Ru Kol moraines, with respect to the present-day snowline, should thus be 558 m. Other determinations, to complement these could be made if the supposed glacial deposits of the Warduj valley present at the mouths of the tributary valleys of Aqshira, Bashun and Tergeran are considered, (cf. page

363). In the case of the first of the three valleys, supposing that the mounds represent a terminal moraine of the old Aqshira glacier, the height of the corresponding snowline would give the following results: height of the Aqshira moraine 1800 m a.s.l., average height of the ridge of the catchment basin 4800 m. The average is 3300 m which, according to the HÖFER method, could represent the height of the snowline. The lowering of the snowline obtained with the same method for the present day North Aqshire glacier is 1100 m. Similar values were obtained for the other two valleys.

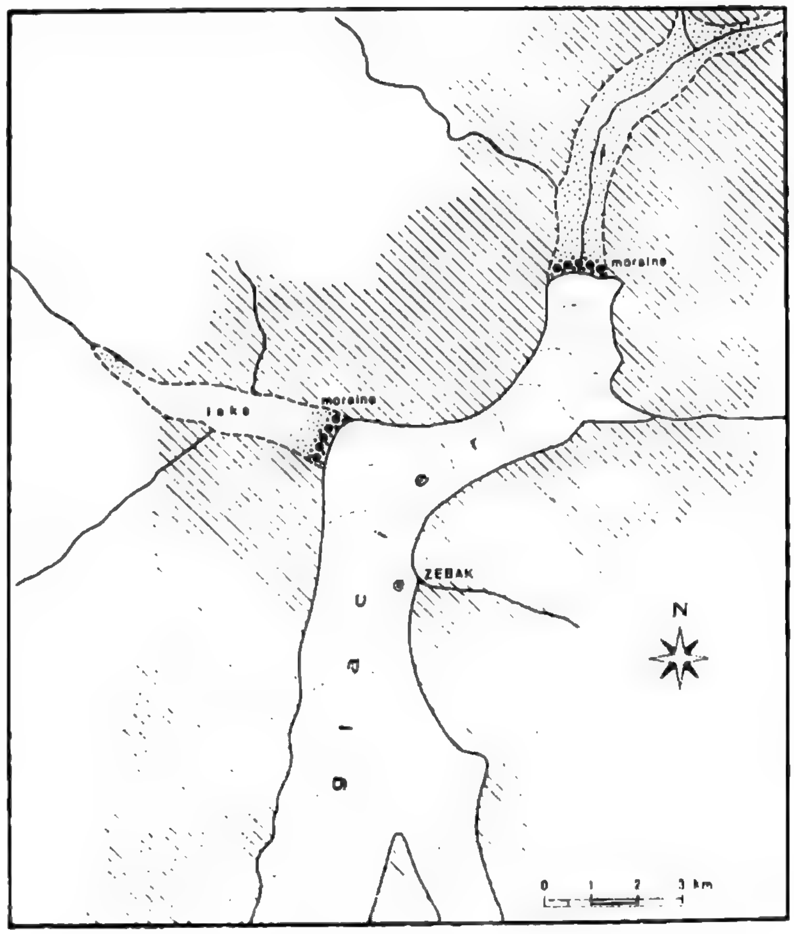

Fig. 44 - The reconstruction of the old glacier in the Zebak valley during the « Zebak stade ».

The results of the calculations concerning the lowering of the snowline with respect to the present day snowline are given below:

Zardew glacier (Baharak moraine)	1200 m
Shakh Darrah glacier	1100 m (?)
Lake Shiwa glacier	680 m
Zebak glacier	558 m

Lateral glaciers (Aqshira, Bashun, Tergeran) of the Warduj valley	1100 m.

The values listed above should be divided into two groups, the first from 1100 to 1200 m, the second from 560 to 680 m. Evidently these two groups cannot be referred to the same glacial phase. The first should be referred to one of the major glaciation; the second to a minor phase of probably post-Glacial time which was called by us, the *Zebak stade*, during which an average lowering of the snowline of about 600 m with respect to the present snowline, occurred.

If these data are compared with those for the Alpine region it should be assumed that the first group represent a glacial episode corresponding to the Würm glaciation of PENCK and BRÜCKNER for which the lowering of the snowline with respect to the present day snowline is 1200 m. On the contrary, a lowering of 600 m would correspond to the second post-Würm stade, that is to that of Gschnitz and not to the first, of Bühl.

At this stage the data collected by us can be compared with those from the neighbouring areas.

In the *Khwaia Muhammad group* GRÖTZBACH & HILLEBRANDT (1969, page 20) calculated a lowering of the climatic snowline for the last glacial expansions of 1300 m with respect to the present day snowline. GRÖTZBACH & RATHJENS (1969, page 62) for the Hindu Kush, between Koh-i-Baba and the Panjshir area, obtained values of 1000-1100 m for the lowering of the snowline.

GRÖTZBACH & RATHJENS created for the lower values two phases, the *Salang Stadium* for the lowering of the snowline of 800 m with respect to the present day snowline and the *Ramayel Stadium* for a lowering of 500 m. The values determined by us do not coincide with theirs. It can be said, however, that the Zebak stade could correspond to the Ramayel if account is taken of the direct relationships between the old glacier and those of the Hindu Kush range like those which were studied by these two authors.

6. THE NUMBER OF PLEISTOCENE GLACIATIONS IN CENTRAL BADAKHSHAN.

In order to determine the number of glaciations which occurred in the studied territory during the Pleistocene, two main elements have been examined. These are the morphological and stratigraphical characteristics of the various glacial deposits and the altitudes of the snowline referred to the terminal moraines.

Two great glacial expansions are sufficiently well documented of which one corresponds to the Zardew terminal moraines and the lower levels of the valley terraces in the middle Shakh Darrah valley and the outlets of certain tributary valleys of the Warduj valley: the other to the upper levels of the valley morainic terraces in the Zebak, Warduj, Zardew and Shiwa valleys and the presumed terminal moraines in the Baharak basin. These are the major glacial expansions in Badakhshan, while the poor traces of a much older glaciation with weathered moraines have still to be confirmed.

As discussed above at the beginning of the chapter, recent research undertaken especially in Pamir and Tadzhikistan, but also in norther Badakhshan by Russian scientists, especially A. A. Nikonov & M. M. Pakomov (1972), has established proof of the existence of three glaciations, one in the Early Pleistocene, one near the end of the Middle Pleistocene and one in the Late Pleistocene. The oldest glaciation (Late Pliocene) is only a hypothesis.

From the brief notes which have been made available very recently it is understood that the studies have followed three lines, that is morphological, stratigraphical and palynological. Thus the conclusions appear to be sufficiently well based even if for the moment detailed documentation and reference to the variations in the height of the snowline relative to the various glaciations is lacking.

It is obvious that there must exist in Badakhshan remains of the three glaciations much more extensive than those noted during the rapid visit made by us to the country. It remains for us therefore to attempt to refer the glacial deposits discussed above to the glaciations which were distinguished by the Russian authors even though they used spore and pollen results.

According to these authors the most widespread glacial horizon in the main valleys of Badakhshan is represented by the « ash grey moraine »

which has been referred to the major glaciation of Middle Pleistocene age. This glacial deposit is present not only along the upper valley of the Panj from Wakhan Dara to Ishkashim but also in the Zebak depression (see page 368) and in the Warduj valley as far as its confluence with the Kokcha, in the Baharak basin, descending from 3300-2800 m to 1400 m. These authors add that under these deposits at several localities fluvio-glacial pebble fans outcrop, which are several tens of metres thick. These occur to a depth of many metres beneath the present river beds and are referred to the previous Interglacial.

These pebbly Interglacial deposits have smaller grain size where the valleys are wider not only in the areas occupied by the glaciers but beyond them as for example near Jurm. The spore and pollen results obtained from the deposits examined at Khash Dara (Jurm) indicate the predominance at that time of xerophytic plants suggesting a hot-dry climate. These therefore are Interglacial deposits laid down immediately before the Middle Pleistocene glaciation.

Spore and pollen results for the lower part of the Khash Dara section indicate the occurrence of another glaciation (Early Pleistocene) preceded in its turn by a period of sub-tropical steppe-like climate of Late Pliocene age.

The age dating of the above mentioned authors given to the moraines in the Baharak basin are less clear. In this connection they observed that the Middle Pleistocene dating of the buried fluvio-glacial formation is confirmed also by the fact that it is covered by more recent moraines which fill the bottom of the glacial valleys in the lower courses of the Zardew and Warduj rivers and block the mouths of the two valleys in the Baharak basin with « fresh well preserved terminal moraines ». The relationship between the « ash grey moraine » and the Baharak moraine is not clear. They are supposed to have formed under separate glacial conditions, one in the Middle Pleistocene which was widely distributed in the area studied, and one in the Late Pleistocene. During the last glaciation also, glaciers developed not only in the cirques, but also in the valleys and these must have reached the main valleys.

Presumably the moraine which blocks the mouth of the Zardew valley can be attributed to this glaciation, as can the Shakh Dara moraine and those occurring near the mouths of the tributary valleys of the Warduj valley

(Aqshira, Bashun, Tergeran), because of the relative freshness of their morphology. On the other hand, the intensely eroded ash-grey glacial deposits (skeletal moraines) around Zebak and in the Warduj valley can be referred to Middle Pleistocene glaciation. Taking into account that this glaciation correspond to a greater expansion of the glaciers than that of the succeeding one, it is reasonable to place the front of the Zardew glacier beyond the moraine which blocks the entrance to the Baharak basin.

As discussed on page 369 it is considered therefore that the moraines of Dasht-i-Feraq and Furmoragh, represent the remains of a terminal moraine which was deposited by the Zardew glacier during the greatest glacial expansion.

It is not possible to say with certainty which are the corresponding glacial deposits in the Warduj valley. In fact it does not appear that this valley was ever entirely occupied by a great glacier during the Pleistocene. The deposit which actually blocks the entrance to the Baharak basin is not a moraine but is formed, as we know, at least at the surface, of landslide material (see page 361).

But this is not a problem because the glacial deposits are numerous upstream in the Warduj valley and it would be difficult to preserve a terminal moraine in a valley with a narrow floor, not to mention that among the moraines seen in the valley more than one seemed to be a possible frontal moraine partly destroyed by streams. Only more accurate research, especially on the petrographic nature of the component material of the various glacial deposits, can clarify this problem definitively. In any case, the terraced moraines 150-200 m above the present valley floor and the skeletal moraines are referable to the older glaciation of the Middle Pleistocene.

It still remains to determine to which glaciation the presumed weathered moraine, mentioned as occurring near the lower end of the upper Shiwa valley, belongs (page 350). Can it be assigned to the Early Pleistocene expansion or to a still older glaciation?

Considering its state of weathering, which was not encountered anywhere in the ash grey moraines, it seems that the latter hypothesis is probably the most acceptable.

The terminal moraine of Lake Shiwa and those around Zebak have still to be correlated using spore and pollen analyses. From determinations of the corresponding altitudes of the snowline it appears that the glacial phe-

nomena are later than those previously considered and classified chronologically by the Russian authors.

They must therefore be attributed, as already done, to one of the post-glacial stages.

To summarize the data presented above in the light of the palynological data of the Russians and our research, in Central Badakhshan there are remnants of two glaciations which can be referred to the Middle and Late Pleistocene. To the latter can be referred the terminal moraine which closes the mouth of the Zardew valley in the Baharak basin and those that occur near the mounths of some tributary valleys of the Warduj.

To the earlier glaciation can be attributed the skeletal moraines (ash-grey moraines) especially widespread near Zebak and in the Warduj valley, but probably present elsewhere. The moraines situated downstream from the Zardew terminal moraine on the floor of the Baharak basin can be referred to this glacial expansion which was probably the greatest. These moraines may represent the remains of an old terminal moraine.

The moraines occurring at higher elevations like those of Lake Shiwa and around Zebak may represent post-Glacial deposits.

Throughout this discussion no attemp has been made to consider the deformation the area could have suffered during the Pleistocene and above all the uplift that various data suggest was important.

The problem is not new and numerous Russian authors have discussed it in the neighbouring Pamir and Tadzhikistan (Nikonov, 1971, 1972). Our rapid survey of the glacial deposits of Badakhshan is insufficient for a solution to be found to this problem.

7. POST-GLACIAL STADES IN BADAKHSHAN.

The deposits and glacial traces located between the lower moraines just mentioned and the present day glaciers will be discussed.

The glacial deposits of the Lake Shiwa and Zebak which were laid down during a recession phase of the largest glaciers, were mentioned above. This stade is marked by a lowering of the snowline of about 680 m for the first, and of 558 m for the second with respect to the present day

snowline. Grötzbach & Rathjens mentioned two stades with lowering of 800 and 500 m respectively. As already mentioned on page 401 the Zebak stade could correspond to the Ramayel stade of the two above mentioned authors, while the data relative to Salang stade appears to be less comparable with ours although the two areas are 300 km apart in a direct line and there are two degrees of latitude between them.

This problem will be discussed latter and the altitudes of other pauses during the retreat of the Pleistocene glaciers will be examined.

In the Lake Shiwa area a frontal morainic arc dams the Ab Kotal valley at about 3400 m, that is 300 m higher than the lake and higher than the presumed height of the glacier front during the previous phase. It is assumed, therefore, that this moraine marks another pause during the retreat of the glacier. This moraine is 800 m lower than the front of the nearby Astan glacier, therefore it is probable that between the two elevations there are other frontal moraines. Investigations of this problem were not carried out in the Lake Shiwa region but other data, both ours and of other authors, concerning the surrounding regions are available.

As already mentioned, glacial deposits are present in the Kurkhu valley 700 m below the end of the present day glacier and well marked terminal moraines are present at 3600 m, that is 300 m below the front of the present day glacier. In the upper Aqshira valley, close to the Kurkhu valley, there are glacial deposits also at 3100-3200 m, that is at about 900 m below the front of the present day glacier. It is assumed that the lower moraines both in the Kurkhu and Aqshira valleys represent moraines of a stade evidently more recent than that of Shiwa and corresponding to that of the Ab Kotal in the Lake Shiwa area. The differences in height are dipendent obviously on the orography. The terminal moraines 300 m lower than the fronts of the present day glaciers and other moraines between these and the fronts which can represent the oscillations of the fronts of the present day glaciers during historical time, remain to be examined.

In this connection it must be remembered that in the Khwaja Muhammad group also, at 300 m below the fronts of the numerous present day glaciers, according to Grötzbach & Hillebrandt (1964) there are more or less well preserved remnants of terminal moraines and others still higher to within a short distance of the present glacial fronts. Other terminal moraines having similar positions were reported by Grötzbach & Rathjens

(1969) also in other parts of the Hindu Kush, like that of Salang, and by Mirwald & Roemer (1967) in Wakhan. This coincidence of data demonstrates that this phenomenon is of a general character for the whole Badakhshan area. Therefore it can be assumed that further investigations could reveal the presence of a series of terminal moraines up to 300 m below the present day glacier fronts. This is true not only in other valleys, but also on the thresholds of the cirques which are free of ice at the present time, but which are close, as far as altitude is concerned, to the present-day snowline.

8. THE LOESS IN CENTRAL BADAKHSHAN.

In the region examined loess occurs extensively in the mountains and it has been necessary to omit some of the outcrops on the enclosed geological map in order to indicate clearly the geology of the area.

Loess is commonly present in the central part of the area investigated on the high mountainous plateau between 2000 and 3000 m. Smaller outcrops occur at greater altitudes and are reduced in size and thickness towards the east and west. Wide areas of loess mask the underlying rocks and the irregular surface giving rise to gently rolling countryside.

The deposits are fine-grained, generally silty or argillaceous, yellowish or greyish in colour and ranging in thickness from a few to as much as thirty metres. Generally they are not stratified, but occasionally show traces of stratification.

The loess is considered by us to be in part an eluvial deposit blown by the wind, and therefore eolian, and in part remouved by rain wash and transported and deposited by washing water. Therefore it is partly also a colluvial and an alluvial deposit.

As far as the age of the loess is concerned, the deposits overlie all the sedimentary formations in Central Badakhshan including the youngest, the Kokcha Formation of Late Cenozoic age. No loess was found on the Taluqan gravel or on the moraines deposited during the last Pleistocene glaciation. Loess deposits up to 35-40 metres thick overlie the highest alluvial terraces on the Kokcha river.

In the area investigated it is considered that the loess was deposited mainly prior to the last glacial expansion under semi-arid, steppe-like climatic conditions. It was best developed in the areas surrounding the glaciated part of Badakhshan. The loess was probably removed from that area by aeolian processes and redeposited over a wide area.

These conclusions have been obtained as a result of the limited field investigations carried out by our expedition.

The loess of northern Badakhshan has been studied in detail recently by A. A. NIKONOV (1971 a) who used the results of wells drilled in the area. The loess deposits have been grouped by NIKONOV into two groups, those of the river valleys, those of the foothill slopes and watersheds. The stratigraphic position of the loess formations, which frequently reveal clear stratification, seems to be clearly defined in the Pleistocene succession which infills the old valley system. They occur in the upper part of these sequences and are underlain first by sand and then by pebble beds with maximum thickness of 120 and 170 m respectively, while the loess does not exceed 50 m.

Among the north Afghanistan loess deposits three types have been distinguished, alluvial, proluvial-diluvial and aeolian deposits. All these deposits can be correlated chronologically with the two glaciations in the Middle and Late Pleistocene. The latter may also be derived in part from reworking of older loess deposits.

Spore and pollen analyses suggest that the loess accumulated in an arid environment similar to the present conditions. At least a part of the loess was transported and deposited by glacial melt waters. The smaller thickness of the Late Pleistocene loess relative to that of the Middle Pleistocene is the result of the limited expansion of the glaciers in Badakhshan during the Late Pleistocene when compared with the Middle Pleistocene. The most recent horizons can be attributed to the loess accumulation in the mountainous areas probably formed as a result of wind action.

Data on one of the loess regions in Asia, e.g. the Shansi (China) should be remembered here.

According to detailed investigations carried out by LIU TUNG-SHENG & CHANG TSUNG-HU (1964), the loess, which is generally called *huangtu* (yellow earth) in China, includes both typical loess and loess-like deposits. The former is mainly original loess, while the latter, generally more or less modified or locally redeposited,

may or may not be interstratified with other deposits. According to the above authors there are in the type area of Shansi four different kinds of huangtu ranging in age from Early Pliocene to Late Pleistocene. These different types can be distinguished using fossils (palynomorphs and mammals), their colour, lithology and the presence of unconformities and old soil horizons.

The total thickness of the type sequence is 121 m, but in other areas it can attain 175 m.

Both author record moreover that the huangtu is widely distributed a higher altitudes on the western and northern rather than on the eastern and southern slopes. Furthermore, it is thickest on the westerly facing rather than the easterly facing slopes.

According to C. HINTZE (1964) in Kataghan the north facing slopes are covered with a greater thickness of loess than the southerly facing slopes. This feature was not seen in the area studied. Loess occurs on the higher slopes of the hills but not on the highest. The thickest loess cover is present in the depressions. Detailed research into this aspect of the loess was not undertaken by us.

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NOTICE

The printing of the present volume required nearly three years and during this long time some new publications concerning our area appeared. Others, published previously, were received with long delay during the correction of the proofs. For these reasons we were able to take only some of them into account introducing few lines within the proofs. We record here the most important of the above mentioned reports.

An asteric marks the works which are mentioned within the text.

AUDEN J. B. (1974) — *Afghanistan-West Pakistan.* In "Mesozoic Cenozoic Orogenic Belts". Special Publ. n. 4 of the Geol. Soc., pp. 234-253, London.

* DESIO A. (1974) — *Karakorum Mountains.* In: "Mesozoic Cenozoic Orogenic Belts.", Special Publ. n. 4 of the Geol. Society, pp. 255-266, London.

* GRATZL K. (1972) — *Hindukusch. Österreichische Forschungexpeidition in den Wakhan 1970.* Akad. Druck. u. Verlagsanst. Graz.

* HEUCKROTH L. E. & KARIM R. A. (1973) — *Afghan Seismotectonics.* "Phil. Trans. R. Soc. Lond.", A. 274, pp. 389-395, London.

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MINISTRY OF MINES AND INDUSTRIES OF THE REPUBLIC OF AFGHANISTAN. DEPARTMENT OF GEOLOGICAL SURVEY (1973) — *Geology and Mineral Resources of Afghanistan.* Kabul.

AFGHAN GEOLOGICAL SURVEY — *Tectonic map of Afghanistam.* (1)

(1) Some data have been introduced within the last proofs.

PLATES

Fig. 1.
Rock-salt mine near Kalafghan (Phot. Desio).

Fig. 2. - Salt and gypsum outcrops near Kalafghan (Phot. Desio).

Fig. 1. - Type section of the Cretaceous Mohammed Aba-Sandstone (Phot. Desio)

Fig. 2. - Type-section of the Cretaceous Baba Darwes Formation (Phot. Desio)

Fig. 1. - Contact between limestone and Palaeocene marls on the south slope of Ambar Koh (Phot. Desio).

Fig. 2. - Bed of oysters (*Fatina beldersaiensis romanowskii* Böhm) in the level 6 of the Ambar Koh type-section (Eocene: Turkestan stage) (Phot. Martina).

Fig. 1. - Conglomerate (Tah Jari Member) of the Kokcha Formation near Bluti. (Phot. Desio).

Fig. 2. - Beds of conglomerate of the Kokcha Formation between Faydzabad and Artin Jelaw (Phot. Desio).

Fig. 1. - Migmatite in the Faydzabad Gneiss one kilometre downstream from Khanaqa (Phot. Desio).

Fig. 2. - Pegmatite dykes within the amphibolite near Sum Darrah (Phot. Desio).

The Bagh-i-Turk (2179 m) in the upper Kishem Valley made up of Jalmish Tonalite. In the lower slope of the mountain the contact of the tonalite with the Farkhar Slate is exposed. The slopes on the right side of the peak are composed of black slates (Phot. Desio)

Fig. 1. - View of the mountain ridge above the village of Arakht composed of the migmatite complex. On the foreground the end moraine on the threshold of the Shiwa cirque (Phot. Desio)

Fig. 1. - The spur at the junction of Deh Gol with the Sanglich valley, near Zebak. The saddle in the spur marks the mylonite outcrop along the Zebak-Munjan Fault (Phot. Desio).

Fig. 2. - Erosional morfology in the granodioritic mylonite near Zebak (Phot. Desio).

Fig. 1. - Moraine at the confluence of the Shiwa valley with the Sakh valley (Phot. Desio).

Fig. 2. - Terraces in the Sakh valley (Phot. Desio).

Fig. 1. - The Lake Shiwa (Phot. Desio).

Fig. 2. - The upper Arakht valley from the slopes above the village (Phot. Desio).

Fig. 1. - The moraine damming the outlet of the Zardew valley (Bakarak moraine) seen from upstream. On the right side the gorge of the river (Phot. Desio).

Fig. 2. - The moraine of the outlet of the Zardew valley from the top to the left hand slope of the valley (Phot. Desio).

Fig. 1. - Moraine rampart of Gul Khana in the Warduj valley near Zebak (Phot. Desio).

Fig. 2. - The outlet of the Warduj valley from upstream and the landslide deposit (on the right in the background) (Phot. Desio).

Fig. 1. - An huge erratic of leucogranodiorite near the Dar-i-Hawdz bridge (Baharak) (Phot. Desio).

Fig. 2. - The rocky hill with the moraines and the terraces of Dasht-i-Feraq. From a hill SW of Furmorah (Baharak). (Phot. Desio).

Fig. 1. - Mounds of glacial drift on the Dasht-i-Feraq terrace (Baharak). (Phot. Desio).

Fig. 2. - A morainic hill NW of the village Dasht-i-Feraq (Baharak). (Phot. Desio).

Fig. 1. - The arcuate of drift mounds of the Kol Dast plain from a hill SW of Furmoragh (Baharak). The outlet of the Furmoragh valley in background (Phot. Desio).

Fig. 2. - The hills made up of gravels in the neighbourhood of Kalafgan (Phot. Desio).

IX. APPENDICES

IX. APPENDICES

A. PALAEONTOLOGICAL APPENDIX

1. MICROPALAEONTOLOGICAL NOTES ON SOME CRETACEOUS-EOCENE SECTIONS IN NORTH-EASTERN AFGHANISTAN (1).

1.1. Introduction.

In the following pages the results of the micropalaeontological investigations carried out on the material collected during DESIO's scientific expedition in 1961 will be briefly exposed.

For each section surveyed and sampled the succession of microfacies and/or of isolated assemblages is described, and a short account on their chronological and ecological significance is given.

Finally, a correlation between the different sections based on their micropaleontological content and/or their microfacies is attempted.

The horizons yielding stratigraphically significant foraminifera are uncommon, therefore a detailed biostratigraphical subdivision is impossible.

The micropaleontological papers concerning the area here considered are scanty. We remember DE CIZANCOURT (1938), who described Upper Cretaceous levels with *Orbitocyclina minima* from Taliqan; CITA and RUSCELLI (1959) who figured *Cuneolina* and *Dicyclina* bearing levels of Cenomanian—Turonian age from Pull-i-Khumri section described in a report of A. DESIO (1960). In the same report other microfossils (*Cibicides, Polymorphinae, Globotruncana* ?, *Ticinella* ? etc.) of the same age are mentioned for the first time in a section in the same Gurguri valley (Panjao), in an other section near the lakes of Band-i-Amir, and on the Band-i-Kataghan, between Pull-i-Khumri and Kunduz.

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(1) By M. B. CITA & I. PREMOLI SILVA.

In this area also Oligocene microfossils are mentioned by DESIO [1]. DE LAPPARENT (1963) found *Orbitoides* and *Siderolites* from the Kamhard Valley. VILLA (1961) illustrated some microfacies of samples collected in the neighbourhood of Ishpushta and Barfaq, considered of Paleogene age.

A number of studies dealing with the region near Kabul and south of it appeared in the last few years, due to various members of the German Geological Mission to Afghanistan. Particularly WEIPPERT (1964) described the Paleogene succession near Doab, south of the area considered here. He gave lists of foraminifera from different levels, referred to the Lower, Middle and Upper Eocene. GABERT (1964) described the Mesozoic Karkar section near Pull-i-Khumri, which was also the object of a paper by DESIO, CITA and PREMOLI SILVA (1965); KAEVER (1965 b) in a paper dealing with the Cretaceous-Tertiary boundary in Northern Afghanistan describes with some details the area south of Ali Abad, where one of the sections here considered has been measured. Both planktonic and benthonic foraminifera are recorded, of Palaeocene, Lower and Middle Eocene age.

WEIPPERT (1968) describes the lithostratigraphic succession of some Mesozoic sections here considered, as for instance the Pull-i-Khumri section, but gives no details as to the fossil successions.

More interesting in the ligth of a stratigraphic and paleogeographic interpretation are some papers by Russian authors, which however do not deal, usually, with the Afghan territory.

Among these, a paper by SOLUN and CHEPOV (1963) illustrates the stratigraphic succession at Tashkurghan, one of the sections here considered.

As stated in the geological section of the present volume, all of the sections here described, during the Lower Tertiary, were belonging to the Upper Amu Darya Depression, therefore the stratigraphic schemes given for the region north of Amu Darya may be followed also for the area situated at the south of the river, in Northern Afghanistan.

According to BYKOVA (1953, 1959), SOLUM & CHEPOV (1963), MOROZOVA, KREJDENKOV & DAVIDSON (1965), VIALOV, NEDELKU & NIZA (1966) etc., the stratigraphic succession of the Upper Amu Darya Depression is summarized in the table 6.

The subdivision adopted by BYKOVA (1953) has been compared with

(1) The microfossils are determined by F. VILLA.

TABLE 6 - Tentative correlation between different biozonations used by Russian authors and the standard (tropical) zonation for the aPlaeocene and Eocene interval.
Column 1: lithostratigraphic subdivisions used in Tadhzikistan;
Column 2: main megafossils present in the different units (after MOROZOVA et al. 1965 and SOLUN and CHEPOV, 1963);
Column 3 and 4: micropaleontological successions (zones and assemblages) recognized by BYKOVA (3) and MOROZOVA et al. (4) in Tadhzikistan;
Column 5: biostratigraphy of Palaeocene and Eocene of Caucasus based on planktonic foraminifera, after SUBBOTINA 1953;
Column 6: Standard tropical zonation based on planktonic foraminifera (after BOLLI 1966, emended);
Column 7: Ages.

1	2	3	4	5	6	7
TURKESTAN BEDS	*Fatina estherazyi* *Fatina böhmi*	Endemic associations with *Rotaliae, Cibicides*		*«Globigerinoides» conglobatus* subzone	*Globigerapsis semiinvoluta*	UPPER EOCENE
				Thin walled pelagic foraminifera zone	*Truncorotaloides rohri*	MIDDLE EOCENE
ALAI BEDS	*Ostrea afghanica* *Ostrea cizancourti* *Ostrea multicostata* *Ostrea turkestanensis*			Acarininids zone: *Acarinina rotundimarginata* subzone	*Orbulinoides beckmanni*	
					Globorotalia lehneri	
				Acarininids zone: *Acarinina crassaformis* subzone	*Globigerapsis kugleri*	
					Hantkenina aragonensis	
SUZAK BEDS	*Ostrea hemiglobosa* *Gryphaea camelus* *Panope vaudini* etc.	Foraminiferal assemblage transitional to the Alai	Foraminiferal assemblage transitional to the Alai	conical Globorotaliid zone	*Globorotalia palmerae*	LOWER EOCENE
					Globorotalia aragonensis	
		Heterostomella pseudonavarroana zone and arenaceaus foram assemblage	*Pseudogaudryina navarroana* zone	Compressed Globorotaliid zone: *Globorotalia marginodentata* subzone	*Globorotalia formosa formosa*	
BUKHARA BEDS: KARATAG horizon	*Gryphaea antiqua* *Amphidonta eversa* etc.	*Globorotalia tadjikistanensis* zone	*Acarinina tadjikistanensis* zone	Compressed Globorotaliid zone: *Globorotalia crassata/ Acarinina intermedia* subzone	*Globorotalia acqua*	UPPER PALAEOCENE
					Globorotalia velascoensis	
BUKHARA BEDS: ARUKTAU horizon	—	Miliolid assemblage	—	*Acarinina inconstans* subzone	*Globorotalia pseudomenardii*	
	Cucullea volgensis *Dosiniopsis fallax* etc.		*Acarinina quadratoseptata* assemblage		*Globorotalia pusilla pusilla*	MIDDLE PALAEOCENE
					Globorotalia angulata	
BUKHARA BEDS: TABAKCHA horizon	*Lucina montensis* *Turritella mariae* *Cerithium* etc.		*Nummulites* ex gr. *solitarius* assemblage		*Globorotalia uncinata*	LOWER PALAEOCENE
					Globorotalia trinidadensis	
					Globigerina pseudobulloides/ Globigerina daubjergensis	
AKDJAR horizon	*Turritella montensis,* *Lucina montensis scalaria* etc.				*Globigerina eugubina*	

the more recent one by MOROZOVA, KREJDENKOV & DAVIDSON (1965) in order to point out that the *Acarinina tadjikistanensis* Zone, referred by BYKOVA to the Suzak beds, is considered by MOROZOVA et al. (1965) as the tompost zone of the Bukhara beds. BRATASH, KHASINA & SHUTSKAYA in a short note published in 1968 discuss the age of the Bukhara beds outcropping on the south side of the Upper Amu Darya Depression, on the basis of their foraminiferal content. Their results are, generally speaking, in good agreement with ours with some minor differences: in fact, their faunas are apparently richer and more diverse, also including keeled globorotalias (namely *G. velascoensis*) which are lacking in our material. The fauna comes from a stratigraphic unit comprised in between the Tabakcha and Aruktau horizons; this horizon is called of « Tama Kuduk » (clay formation), has a thickness of about 40 m and is considered of limited geographical extent.

It might be the stratigraphic expression corresponding to the hiatus generally observed in this area above the Tabakcha horizon. The unconformity indicated in between the Tabakcha and Aruktau horizons, however, suggests that the sedimentary succession is interrupted. Moreover, some of the taxa recorded are mutually exclusive, as *Globorotalia velascoensis* and *G. ehrenbergi* or *G. angulata*, which should indicate that the older forms are reworked.

Finally, PREMOLI SILVA (1970) describes and illustrates the foraminiferal faunas here treated. Therefore, reference is made to this paper for paleontological documentation.

The sections here considered range from the Lower (?) Cretaceous to the Eocene and will be described in the following order:

1 - Qara Tut section and Archa Kotal outcrop,
2 - Baba Darwes section and Mohammad Aba outcrop,
3 - Farkhar section,
4 - Pull-i-Khumri sections,
5 - Barfaq section,
6 - Ambar Koh section,
7 - Ali Abad section,
8 - Tashkurghan section.

The first five sections follow one another in the direction NE-SW, and are situated along the outer margin of the sedimentary basin (Upper Amu Darya Depression). The last three are located west of the preceding ones,

as may be seen in text-fig. 27 page 147) and belong to the middle part of the basin, where Tertiary sediments are prevailing in outcrop.

Further information about the micropalaeontological content of the considered sections and a thorough description of the species of foraminifera classified, will be found in the volume dedicated to the Paleontology of northeastern Afghanistan (PREMOLI SILVA, 1970).

1.2. Qara Tut Section.

This section surveyed and sampled by A. DESIO underlies the Baba Darwes section and consists mostly of sandstones and/or conglomerates; the microfacies are always barren and almost useless for correlation. The total thickness is of about 375 m and the studied samples are 11 (see fig. 12, page 77).

From bottom to top we found:

61 AD-48/1 - Orthoquartzose sandstone with clastics of different size, more or less rounded. The dominant constituent is quartz. Minor constituents are turmaline, zircon, muscovite, sericite, iron-ore, etc.

61 AD-48/2 - Quartzitic sandstone similar to the preceding one, in terms of components and texture (see Pl. 1, fig. 4).

61 AD-48/3 - Quartzose siltite with clayey cement. Minor constituents are chlorite, muscovite, sericite, turmaline, zircon, iron-ore, etc.

61 AD-48/4 - Minute quartzitic sandstone containing moulds of plants, rare mica flakes, iron-ore, zircon, etc.

61 AD-48/5 - Conglomerate consisting chiefly of quartz elements, lithic fragments and sericite. Subordinately of muscovite, zircon, iron-ore, etc.

61 AD-48/6 - Quartzose coarse-grained sandstone. Principal constituents are quartz, feldspar, muscovite, chlorite, lithic fragments. Minor constituents: turmaline, zircon, calcite, iron-ore, etc.

61 AD-48/9 - Fine-grained sandstone consisting chiefly of quartz, feldspar, muscovite, lithic fragments. Minor constituents: zircon and iron-ore.

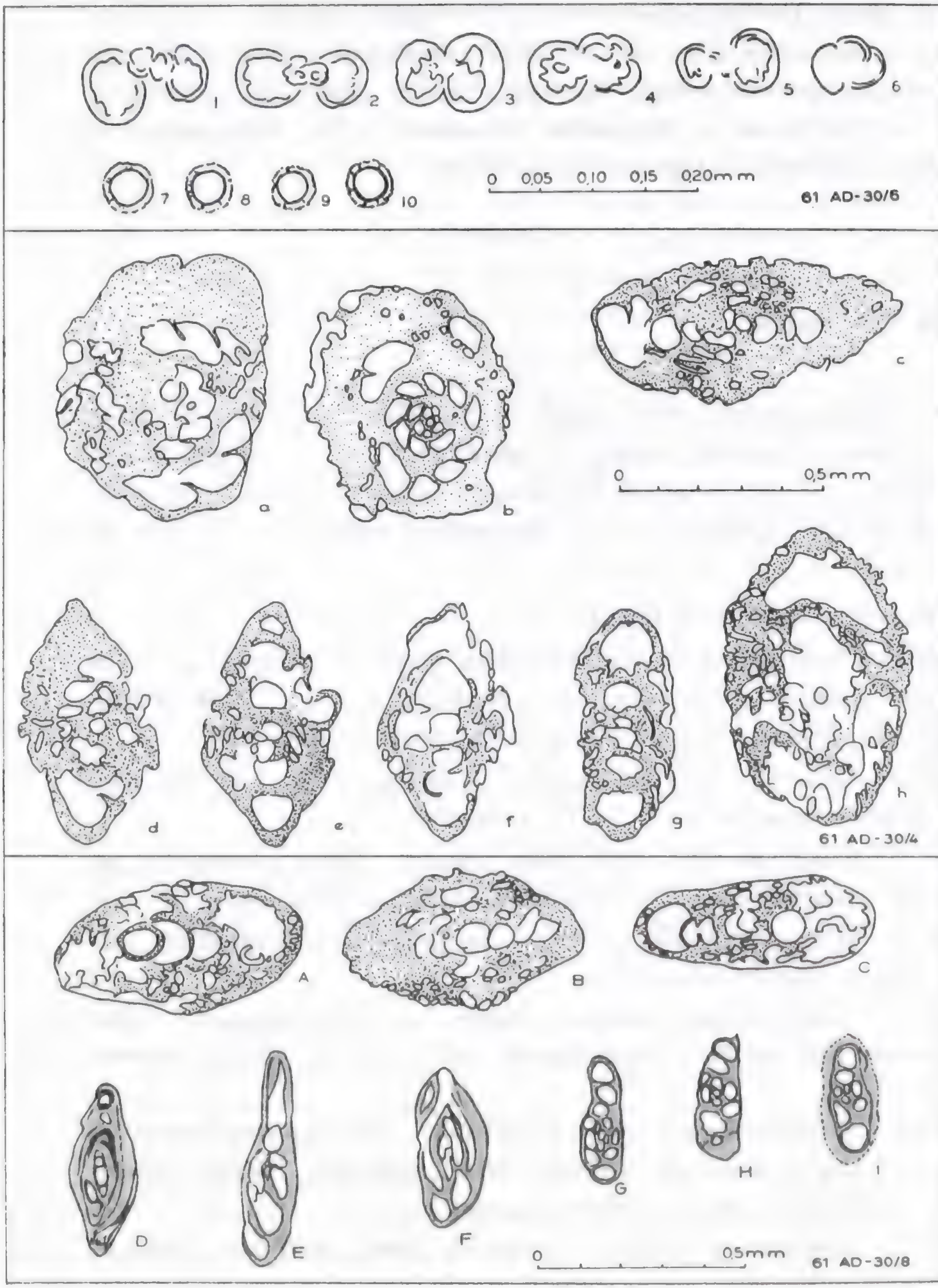

Fig. 1 a - 1-6: axial or oblique sections of *Hedbergella* sp; 7-10: *Stomiosphaera* sp. Daba Dadwes section, level 61 AD-30/6. a, b: equatorial or subequatorial sections of *Haplophragmoides greigi* (HENSON); c, d, e: axial or subaxial section of *Haplophragmoides greigi* (HENSON); f, g, h: subaxial sections of *Haplophragmoides sp.* Baba Darwes section, level 61 AD-30/4. A-C subaxial sections of *Haplophragmoides* sp.; D-F: longitudinal sections of *Ophtalmidium* sp.; G-I: trasverse sections of *Ophtalmidium* sp. Baba Darwes section, level 61 AD-30/8.

61 AD-48/11 - Compact micrite crossed by numerous crystalline calcite veins and containing numerous elongated crystals (geminated) sometimes branched, which possibly represent autigenous anhydrite crystals secondarily substituted by calcite (see Pl. 1, fig. 3).

61 AD-48/18 - Medium-grained sandstone. Principal constituents are quartz, feldspar, calcite. Minor constituents: chlorite, sericite, iron-ore.

61 AD-48/ 18 a - Sandy biosparite abundantly recrystallized, partly dolomitized, containing rhombohedral crystals of dolomite. Quartz grains, glauconite, iron-ore are also present. The organic content is given chiefly by gastropodes and fragments of echinodermata.

61 AD-48/18 b - Sandy, fossiliferous biosparite. The quartz granules are partly inside the oolites, partly in the cement. The organic content consists of molluscan shells, fragments of echinodermata and of bryozoa; rare small foraminifera, echinoid spines and also probable articles of *Saccocoma* may be observed inside the oolites.

The described succession mainly consists of detrital sediments: the only calcareous level (61 AD-48/11) is quite different from all the limestones analyzed in the present study and cannot be correlated with them.

We point out that, as far as we can judge after the samples we were able to examine, the lower part of the section (levels 1 to 4 included), for a thickness of about 309 m is characterized by orthoquartzites or quartzitic sandstones in which the largely dominant component is quartz, while the middle and upper part of the section consists of less elaborated sediments (sandstones rich in feldspar and/or lithic fragments).

A chronological determination is impossible, due to the lack of any significant fossil.

ARCHA KOTAL OUTCROP. At Archa Kotal E. MARTINA collected two samples which correspond to the basis of the Qara Tut section.

61 AE-77/1 (the lower one), is represented by an oo-biosparite with molluscan fragments (gastropodes, probable *Ostreae*), echinodermata, corals, rare *Miliolidae* etc. Some fragments of glauconite are also present.

61 AE-77/2 - Recrystallized biosparite with molluscs, bryozoa, echinodermata and *Dasycladaceae* (?). Glauconite is rare.

1.3. Baba Darwes Section.

This section, characterized by prevailing limestones, has been surveyed and sampled in 1961 by A. Desio (see fig. 12, page 77). We could examine 11 samples, all of them in thin section except the clayey level 2, which has been washed. We do not described here the isolated samples coming from the same area, though richly fossiliferous and interesting for chronological purposes, but we shall consider them later.

From bottom to top, we found:

61 AD-30/2 - Washing residue abundant, given for the greatest part by indisgregated fragments of grey marly limestone with gypsum and iron-ore. No organic content.

61 AD-30/8 - Oo-intrasparite with oolites partly destroyed. The organic content is poor and consists of minute molluscan and echinodermata fragments. Foraminifera are rare (*Lituolidae, Ophtalmidiidae*) (see fig. 1 a).

61 AD-30/6 - Bio-intramicrite partly recrystallized, passing to intrasparite with various organic fragments, rounded and partly oolitized. Molluscan fragments, probable *Dasycladaceae*, planktonic foraminifera (*Hedbergellae*), *Stomiosphaerae, Rotalina* (?), etc. are present.

61 AD-30/3 - Impure bio-intramicrite locally recrystallized, with abundant molluscan debris, calcareous algae, rare ostracodes, arenaceous foraminifera: *Cuneolinae, Dicyclinae, Haplophragmoides, Ophtalmidiidae, Miliolidae*, etc. (see Pl. 1, fig. 2).

61 AD-30/9 - Fossiliferous micrite with abundant quartz clastics, fragments of mollusks among which rudists, *Cuneolinae, Miliolidae*, rare fragments of *Dicyclinae*, rare *Rotaliae*, etc.

61 AD-30/4 - Recrystallized bio-intrasparite rich in crinoid remains (encrinite), with abundant bryozoa and molluscan fragments. Foraminifera are rare, mostly with arenaceous tests: *Lituolidae* among which *Haplophragmoides greigi* (Henson), *Cuneolinae, Rotaliidae*. Rare *Calcisphaerulidae* (*Stomiosphaera*) are noticed too.

61 AD-30/10 - Biosparite rich in fine molluscan debris, *Melobesiae* with well preserved structures, arenaceous foraminifera, *Rotaliae* (?).

61 AD-30/7 - Impure, fossiliferous intrasparite with badly preserved organogenic content, including bryozoa, molluscan fragments, *Melobesiae*,

Miliolidae, *Haplophragmoides*, *Cuneolinae* and *Dicyclinae* possibly reworked.

61 AD-30 - Bio-intra-microsparite with detrital quartz, containing bryozoa, *Rotaliae*, orbitoidal foraminifera including *Orbitoides media*, etc. Isolated embrios of orbitoids are frequent in the section (see fig. 2 a).

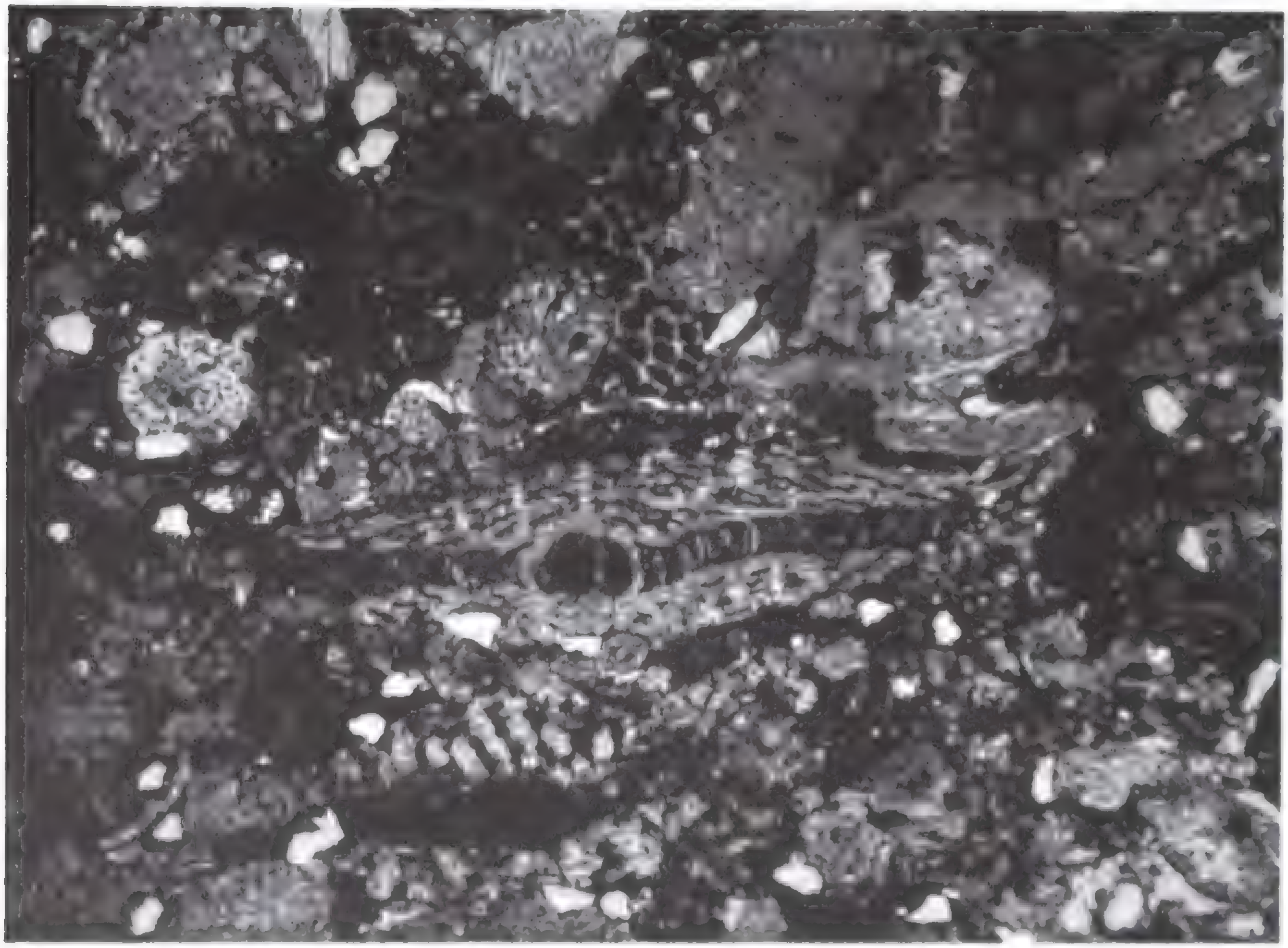

Fig. 2 a - Thin section from level 61 AD-30, Baba Darwes Section, Campanian- Maastrichtian. - Bio-intramicrite with detrital quartz, containing bryozoa, *Melobesiae*, various organic debris and (at the centre) *Orbitoides media* (D'ARCHIAC) in axial section, × 30.

61 AD-30/3' - Sandy foraminiferal bio-intramicrite rich in bryozoa and *Melobesiae*. Foraminifera belong to the genera *Omphalocyclus, Siderolites, Orbitocyclina* (with *O. minima* (Douvillé)) and *Rotalia* (very large specimens) (see Pl. 1, fig. 1).

61 AD-30/5 - Bio-intramicrite with detrital quartz, yielding fragments of different shells, bryozoa, *Rotaliae* and orbitoids in fragments, badly preserved.

The Baba Darwes section is not figured in the log because the relative thickness of the various levels has not been measured in detail. The section is interested by faults (see page 76).

The micropaleontological content of this section is the most interesting from a stratigraphic as well as paleoecological standpoint.

From bottom to top we recognized:

a level with planktonic foraminifera;
a level with *Cuneolinae* and *Dicyclinae*;
a level with *Orbitoides media*;
a level with *Orbitocyclina minima, Omphalocyclus* and *Siderolites*.

The level with planktonic foraminifera immediately overlies the oolitic limestone and shales and indicates a marked transgression of the Cretaceous sea. In terms of chronological significance, the assemblage surely indicates a Cretaceous age. The only genus represented is *Hedbergella* (*Globigerina* auctorum) while *Rotalipora* and *Praeglobotruncana* are totally absent. The dimensions of *Hedbergellae* are small, and their evolutionary stage rather primitive, therefore one should conclude for an uppermost Lower Cretaceous (Albian ?) age. The absence of the cited more evolved planktonic genera might be due to ecological more than to chronological factors (indeed the sediment is rather coarse-grained and also the organic content is not typical for the pelagic environment). Therefore we cannot exclude a Cenomanian age for this level.

The level rich in *Cuneolinae* and *Dicyclinae* contains also a rudist typical for the Cenomanian: *Ichtyosarcolites triangularis* DESMAREST, and both foraminifera and rudist indicate the same age.

The last two levels, more recent in age, are attributable to the Campanian-Maastrichtian. According to VAN HINTE (1966), we believe that the assemblage with *Orbitoides* s.s. is slightly older than the level with *Orbitocyclina minima.*

In conclusion, an attribution of the first (lower) two levels to the Albian-Cenomanian and of the topmost ones to the Maastrichtian is well documented. However, we have no indications of the stratigraphic interval intermediate between the two. Therefore a hiatus corresponding to a large part of the Turonian and Senonian succession is advanced as a working hypothesis.

Sample 61 AD-30/7 may be interpreted as corresponding to the trans-

gressive horizon, including fragments of fossils belonging to the underlying Cenomanian-Turonian formation.

The entire Baba Darwes section is composed by limestones indicating a sublittoral and/or littoral marine environment. Oolites are common in some levels, and a certain detrital amount is present throughout the section. The only pelagic organisms noticed are *Stomiosphaerae* and *Hedbergellae*, represented by fairly numerous specimens in levels 61 AD-30/4 and 61 AD-30/6. Though associated with an assemblage of bryozoa, mollusks, imperforated foraminifera which indicate a shallow water environment, their presence demonstrates a pelagic influence in the deposition, prior to the typically littoral sedimentation of the Maastrichtian (orbitoidal limestones).

MOHAMMAD ABA OUTCROP. Near Mohammad Aba DESIO collected and described samples from two joint levels belonging to the lowest part of the Baba Darwes formation.

61 AD-34/2, the lower level, is characterized by a fine-grained sandstone with clayey matrix. Glauconite is frequent. The organic content consists of sponge spicules, rare molluscan fragments and small planktonic foraminifera (*Hedbergellae*) (see fig. 3 a).

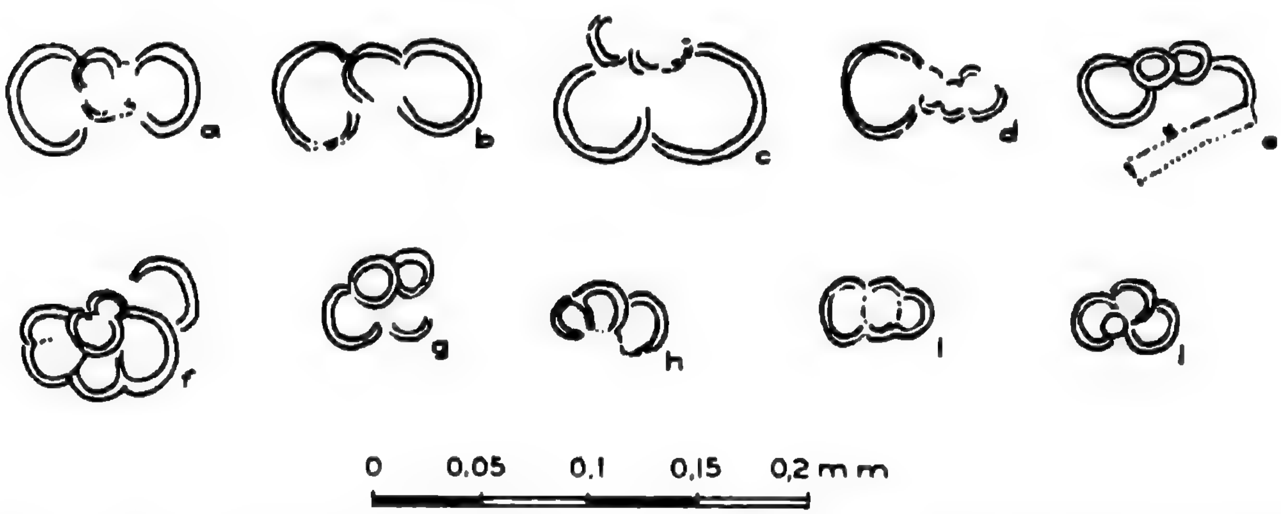

Fig. 3 a - Axial or subaxial (a-e), equatorial (f) and oblique (g-l) sections of small *Hedbergellae* contained in sample 61 AD-34/2 from the Mohammad Aba outcrop. Due to the small size and to the low evolutionary stage of the planktonic foraminifera, the age of this level, which underlies the *Cuneolinae*-bearing one, is probably Albian.

61 AD-34/1, the upper level, is a biomicrite with *Cuneolina pavonia parva*, *Dicyclina schlumbergeri* and arenaceous forms (*Haplophragmoides*,

Pseudotextulariella sp., etc.), *Miliolidae*, molluscan and bryozoan fragments.

Among the megafossils collected in the upper level we remember *Gryphaea vesicularis* and *Actaeonella cylindracea*, which indicate a Cenomanian-Turonian age, in agreement with the age indicated by the foraminiferal assemblage. The same superposition of the *Cuneolina* and *Dicyclina* bearing beds to the level with small *Hedbergellae* occurs as observed in the Baba Darwes section.

CHENAR-I-GUNJESHKAN PASS OUTCROP. North-west of Baba Darwes a sample 61 AD-35/1, which may be correlated with the topmost part of the Baba Darwes section is characterized by a biosparite with *Orbitocyclina minima* and bryozoa. Orbitoids, *Omphalocyclus, Rotaliidae, Melobesiae*, molluscan fragments etc. are also present (see Pl. 5, fig. 4). The age of the assemblage is Maastrichtian, as indicated by the joint presence of the genera *Orbitoides, Omphalocyclus* and *Orbitocyclina*.

1.4. Farkhar Section.

This section, the thickness of which is of about 265 m, has been measured and samples by MARTINA in 1961 (see fig. 5, page 48).

The micrographic characters observed in the thin sections obtained from the eight rock samples analyzed, and the two washing residues are as follows, from bottom to top:

61 AE-87/4 - Sandy microsparite, partly dolomitized, with very rare arenaceous foraminifera.

61 AE-87/5 a - Fossiliferous intramicrite with molluscan fragments, filaments, and very rare arenaceous foraminifera.

61 AE-87/5 b - Thin sections obtained from the following sample were strongly different from one another. We observed:

a) red oosparite with molluscan shell fragments, echinoid spines and plates, bryozoa, some detrital quartz outside and inside the oolites, which are strongly irregular in shape and size, and some alterated glauconite (see Pl. 2, fig. 4).

b) fossiliferous intramicrite very rich in bryozoa (see Pl. 2, fig. 3).

c) biomicrite very rich in shell fragments (probably *Ostreae*), with abundant detrital quartz in small sized granules.

61 AE-87/6 - Pelletiferous micrite with dark melted oolites and very small crystals of dolomite. The organic content is given by thin calcitic filaments, small ostracods and rare *Miliolidae.*

61 AE-87/7 - Washing residue poor, composed by arenaceous fragments, abundant, transparent and/or milky gypsum crystals, calcite, without any organic content.

61 AE-87/9 - Oosparite with molluscan fragments, echinoid spines, foraminifera (*Lituolidae, Glomospira, Ophtalmidiidae,* see fig. 4a) often observed inside the oolites.

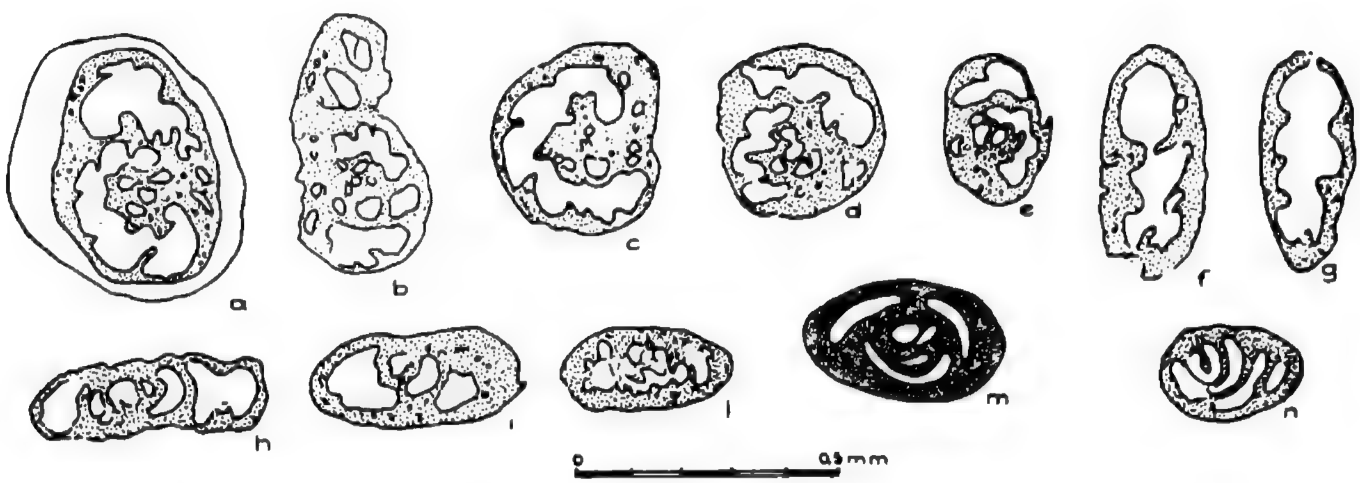

Fig. 4 a - Sections of *Ammobaculites* (a, b, f, g), *Haplophragmoides* (c, d, i, l), *Ophtalmidium* (m) and *Glomospira* (n) from sample 61 AE-87/9 of the Farkhar section. It is impossible to give a precise age assignement to this sample, which is surely pre-Albian since it underlies lev. 61 AE-87/11 (see Fig. 5).

61 AE-87/10 - Washing residue almost entirely constituted by rounded laminae and crystals, some of which geminated, of gypsum, mostly transparent, with rare arenaceous grains, barren.

61 AE-87/11 - Fossiliferous micrite with quartz grains and some dolomite crystals. The organic content is given by fragments of mollusks, echinoid spines, fairly abundant small planktonic foraminifera (*Hedbergellae*, among which *H. delrioensis* (Carsey) (see fig. 5a). (See also Pl. 2 fig. 2).

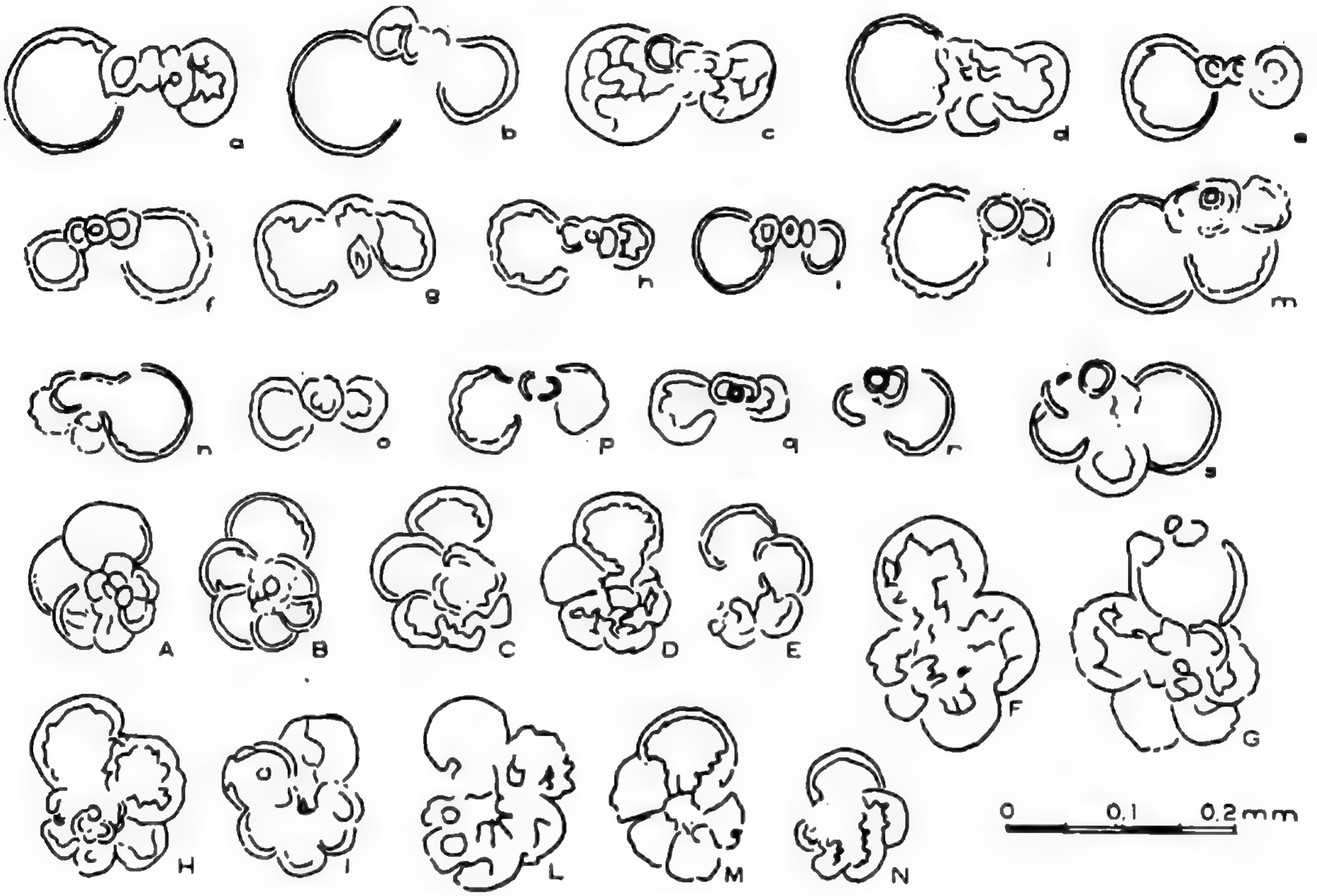

Fig. 5 a - Avial and/or subaxial (a-l, o-r), oblique (m, s) and equatorial (A-N) sections of *Hedbergellae*. Specimens represented in D, G, N may be referred to *Hedbergella delrioensis* (CARSEY), which ranges from the Albian to the Cenomanian. Farkhar section, level 61 AE-87/11.

61 AE-87/12 - Biomicrite passing to fossiliferous micrite with molluscan fragments and echinoid spines, abundant *Cuneolinae* and *Dicyclinae*, particularly *Cuneolina pavonia parva* and *Dicyclina schlumbergeri*, *Lituolidae*, *Valvulinidae*, *Miliolidae*, etc. (see Pl. 2, fig. 1).

61 AE-87/13 - Poorly washed biosparite with molluscan fragments (partly belonging to the rudists), abundant *Cuneolinae*, *Dicyclinae*, *Miliolidae* and *Lituolidae*: particularly *Haplophragmoides* cf. *greigi*, *Cuneolina pavonia parva*, *Dicyclina schlumbergeri*.

The micropaleontological content of this section is very interesting from a stratigraphic as well as paleoecological standpoint in its upper part, where two levels are well characterized; the former with planktonic foraminifera, the latter with *Cuneolinae* and *Dicyclinae*.

The level bearing planktonic foraminifera immediately overlies the eva-

porites and indicates a marked transgression. Though rich, the assemblage yielded only one form identifiable at a species level: *Hedbergella delrioensis* (CARSEY), which ranges from the Albian to the Cenomanian. The lack of more evolved planktonic foraminifera suggests an Albian age for this level, which stratigraphically underlies the *Cuneolinae* and *Dicyclinae* bearing level, of Cenomanian-Turonian age.

1.5. Pull-i-Khumri Sections.

This section is composed of: a lower part (a) 80 m thick, an upper part (b), partly overlapping the preceding one, 170 m thick (see fig. 19, page 108).

The survey of the Pull-i-Khumri sections has been done by MARTINA in 1961; the same section had been previously described by DESIO (1959) and some news about its micropaleontological content may be found in a note by CITA & RUSCELLI (1959). 32 rock samples have been submitted to a micropaleontological research, 26 of which were studied in thin sections, the remaining 6 as washing residues.

From bottom to top, we found:

SECTION A.

61 AE-97/3 - From a cross-bedded sandstone we obtained an abundant washing residue consisting of quartz grains, frequently rounded and impure, more rarely hyaline, rare oxydated fragments, gypsum laminae, calcite crystals etc. No organic content.

61 AE-97/5 - Washing residue consisting of more or less oxydated calcite grain, quartz, often hyaline, indisgregated calcitic and quartzose grains. Barren.

61 AE-97/6 - Washing residue given by small-sized gypsum crystals agglutinated by means of a red marly (?) matrix and containing besides frequent laminae and crystals of gypsum, rare fragments of iron-ore and calcite crystals. No organic content.

61 AE-97/7 - Sandy oosparite passing to orthoquartzite cemented by sparitic calcite with oolites. The texture is very fine, since the average size

of oolites and of quartz grains is of about 0.5 mm. The organic content is scattered and cannot be surely referred to any group of organisms, being reduced in small unrecongizable fragments (see Pl. 4, fig. 4). This microfacies perfectly corresponds to that of sample 61 AE-95/1, belonging to section B, thus enabling us to establish a correlation between the two sections.

61 AE-97/8 - Orthoquartzitic sandstone, with calcareous (microsparite) cement, with oolites, rare molluscan shell fragments (*Ostreae* ?) and very rare foraminifera.

61 AE-97/9 - Dolomitized biosparite containing clastics of quartz and of partly alterated glauconite. The organic content consists of molluscan shells, echinoid spines and plates, bryozoa.

61 AE-97/10 - Sandy and oolitic biosparite. The quartz is present also inside the oolites. The organic content is given by molluscan fragments, bryozoa, *Melobesiae*, echinoid debris etc.

61 AE-97/11 - Biosparite with oolitized fossils and frequent oolites, sometimes with quartz grains in the nuclei. Abundant quartz clastics. Fragments of molluscan shells, small gastropods, bryozoa, echinoid debris, *Melobesiae* are present.

61 AE-97/12 - Dolomitized biosparite, containing badly preserved fossils, partly recrystallized, mostly mollusks, subordinately bryozoa and echinoid debris.

SECTION B.

61 AE-95/1 - Oosparite with abundant detritic quartz. This sample may be correlated to 61 AE-97/7 for the strict analogy of their microfacies (see Pl. 4, fig. 3).

61 AE-95/2 - Sandy biosparite passing to fossiliferous orthoquartzite with calcitic cement, and containing altered glauconite. The organic content is abundant and given chiefly by molluscan shells and subordinately by bryozoa colonies.

61 AE-95/3 - Biosparite (sandy microsparite) passing to fossiliferous orthoquartzite. Zones largely recrystallized are noticed, and rare oolites. Molluscs, bryozoa and echinoderms are present in fragments. This microfacies is very similar to 61 AE-97/10.

61 AE-95/4 - Sandy biomicrite partly recrystallized. The rock is extremely rich in bryozoa, molluscs, echinoid fragments (see Pl. 4, fig. 2).

61 AE-95/5 - Oo-biosparite. The nucleus of a great number of oolites is composed of quartz grains. Bryozoa dominate the organic content, followed by molluscan debris and probable *Dasycladaceae*.

61 AE-95/6 - Fossiliferous oosparite passing to biosparite. Many oolites contain detrital quartz, other ones sections similar to *Saccocoma*; bryozoa, molluscs and echinoid fragments are present in decreasing quantities.

61 AE-95/7 - Washing residue scarse, red in colour, consisting of rounded fragments of red limestone. Numerous gypsum laminae are present some of which have a lenght up to 2 mm. Some calcite crystals are present too. The organic content is given by ostracods, rare gastropod moulds and arenaceous foraminifera, among which: *Ammobaculites, Recurvoides* and *Spirophtalmidium*.

61 AE-95/8 - Barren sparite.

61 AE-95/9 - Alterated biosparite entirely recrystallized, rich in molluscan (?) fragments.

61 AE-95/10 - Washing residue scarse, red in colour, consisting of fragments of indisgregated limestone, which sometimes are limonitized. Rounded gypsum grains are frequent, while iron-ore is rare. The organic content consists chiefly of deeply eroded colonies of bryozoa and very rare foraminifera, from which: *Gaudryina* sp.

61 AE-95/11 - Barren sparite.

61 AE-95/12 bis - Fine-grained sandstone composed by quartz, two micas, and calcite, with rhombohedral crystals of dolomite. Barren.

61 AE-95/13 - Bio-intrasparite with molluscs and foraminifera (fragments of *Cuneolinae, Dicyclinae, Miliolidae, Ophtalmidiidae, Lituolidae*).

61 AE-95/13 bis - Sandy intra-biosparite passing to quartzose sandstone with quartz crystals, sometimes large-sized, molluscan shells, *Melobesiae*, badly preserved foraminifera, among which *Cuneolinae*, *Dicyclinae, Lituolidae, Miliolidae* etc.

61 AE-95/14 - Washing residue scarse, given for about 80% by gypsum in rounded and/or geminated elements, and subordinately by arenaceous grains, sometimes rich in iron-ore, strongly alterated. Rare oolites. Foraminifera are rare and belong chiefly to the *Lagenidae*.

61 AE-95/15 - Bioclastic limestone containing fragments of cataclastic quartz, orthose in idiomorphic crystals perfectly preserved, fragments of quartzite and chert. Fragments of molluscan shells are abundant in the sparitic cement.

61 AE-95/16 - Very fine quartzose-micaceous sandstone containing dolomite crystals. Quite barren.

61 AE-95/17 - Recrystallized bio-intrasparite, containing molluscan fragments, echinoid spines and plates, bryozoa, rare arenaceous foraminifera, fragments of corals. Among the intraclasts one may recognize some *Stomiosphaerae*.

61 AE-95/18 - Dolomitized biomicrite, with fragments of mollusks, echinodermata, and bryozoa. Some glauconite in small grains is observed.

61 AE-95/20 - Intra-biosparite with neoformated dolomite containing molluscan shells, echinodermata, well developed and preserved bryozoa colonies; *Stomiosphaerae* are observed among the intraclasts.

61 AE-95/21 - Intra-biosparite with molluscs, bryozoa, echinoids and *Melobesiae*. A small amount of detrital quartz is present among the intraclasts, as well as glauconite grains (rare), *Stomiosphaerae* and some foraminifera (*Textulariidae*, *Valvulinidae*, *Lagenidae*, *Discorbidae*).

61 AE-95/22 - Impure biosparite, strongly dolomitized, with corals, bryozoa, echinoid spines and plates, *Inoceramus* prisms and *Stomiosphaerae* (see Pl. 4, fig. 1).

There is a fairly good correspondence between the Pull-i-Khumri sections here described and the one studied in 1959 by CITA & RUSCELLI from the same locality. The level with *Cuneolinae* and *Dicyclinae* has been recognized in both sections and is the one having a stratigraphical significance: other microfacies, though fossiliferous, cannot be used for chronological purpose. WEIPPERT (1968) in his study of the North Afghanistan Cretaceous also considers the Pull-i-Khumri section, both lithologically and paleontologically. He records an horizon with *Orbitolina lenticularis* BLUMENBACH, which is not represented in the actual collection investigated nor in the collection studied by CITA & RUSCELLI (1959). The same author does not record the horizon with *Cuneolinae* and *Dicyclinae*.

In a genesal way, the considered section cannot be precisely defined from a chronological point of view in its lower and upper limits. It certain-

ly belongs to the Cretaceous and probably entirely to the Upper Cretaceous, but we lack a sure evidence for the latter assumption.

On the base of the microfacies observed, the environment in which the sedimentary sequence of Pull-i-Khumri has been deposited is shallow marine, nearshore for the greatest part. Oosparites and biosparites are among the best represented lithologic types: the organic content, given by bryozoa, molluscan fragments, echinoid spines, calcareous algae and sometimes by imperforated foraminifera is of sublittoral to littoral significance. The pelagic organism are completely absent, except for some *Stomiosphaerae* present in the topmost levels of section B; these forms, however, are inside the intraclasts anr therefore possibly do not belong to the local environment.

1.6. Barfaq Section.

This section has a total thickness of about 290 m and has been measured and sampled by MARTINA in 1961 (see fig. 20, page 115).

We were able to examine 9 samples, 7 of which studied in thin section, the remaining two washed.

From bottom to top we found:

61 AE-100/8 - Pelletiferous microsparite with abundant clastics consisting of quartz crystals, and/or cavities let behind by them. No organic content.

61 AE-100/7 - Micrite partly pelletiferous with intraclasts, abundant rounded quartz grains. Fossils are rare and consisting of large *Rotaliae* (see Pl. 3, fig. 2).

61 AE-100/6 - Impure argillaceous micrite with pelletiferous (?) structure and containing rounded quartz grains.

61 AE-100/5 - Biomicrite with abundant *Miliolidae, Ophtalmidiidae,* large *Rotaliae,* and arenaceous foraminifera. The genera *Quinqueloculina, Spirophtalmidium, Clavulina* may be recognized (see Pl. 3, fig. 1).

61 AE-100/4 - Poorly washed intra-biosparite with *Miliolidae, Ophtalmidiidae,* arenaceous foraminifera, *Lagenidae, Rotaliae,* calcareous algae (*Melobesiae* and possibly *Dasycladaceae*), molluscan fragments.

61 AE-100/3 bis - Biosparite with *Miliolidae* and arenaceous foraminifera, *Cibicides*, molluscan and echinoid fragments, *Melobesiae*.

61 AE-100/3 - Washing residue abundant consisting of indisgregate arenaceous granules, glauconite, mica flakes, green rocks etc. Foraminifera are abundant, but usually not well preserved. The most represented genera are *Marginulina*, *Robulus* and *Cibicides*. Also present *Gyroidina*, *Astacolus*, *Nodosaria*, *Guttulina*, *Frondicularia*, arenaceous foraminifera among which *Trochammina*, rare planktonic forms, frequent ostracods and echinoid spines.

The following species have been recognized (see Pl. 6, fig. 2):

Allomorphina conica Cushman & Todd
Bulimina ovata d'Orbigny
Cibicides rigidus Bykova
Cibicides succedens Brotzen
Dentalina cf. *communis* (d'Orbigny)
Gyroidina aff. *angustiumbilicata* Ten Dam
Gyroidinoides soldanii octocamerata (Cushman & Hanna)
Karreria fallax Rzehak
Marginulina longiforma (Plummer)
Nodosaria bacillum Defrance
Nodosaria bacillum minor Hantken
Robulus roemeri (Reuss)
Spiroplectammina monetalis Bykova
Trochammina sp.
Uvigerina elongata Cole
Virgulina schreibersiana Czjzek
Globorotalia ehrenbergi Bolli
Globorotalia quadratoseptata (Davidson & Morozova)
Globigerina mckannai White
Globigerina cf. *microsphaerica* (Morozova)
Globigerina triloculinoides Plummer

61 AE-100/2 - Impure biosparite with mollusks, *Miliolidae*, and *Melobesiae*. *Cibicides*, *Rotaliae*, possibly *Planorbulinidae* and related genera are also present, as well as echinoid fragments and bryozoa.

61 AE-100/1 - Washing residue abundant, consisting of fragments of indis-

gregate sandstone, of quartz grains, mica flakes, glauconite etc. Foraminifera are rare (*Miliolidae, Cibicides* etc.).

This section cannot be dated accurately after its micropaleontological content owing to the lack of significant fossils.

The most interesting bed is 61 AE-100/3, which yielded a planktonic assemblage including *Globorotalia ehrenbergi, G. quadratoseptata, G. mckannai, Globigerina triloculinoides* etc. *Globorotalia quadratoseptata,* according to the planktonic foraminiferal biostratigraphy used by some Russian authors (see MOROZOVA, KREJDENKOV & DAVIDSON, 1965) is considered as zonal marker for the middle Palaeocene.

The level discussed above overlies a level very rich in *Miliolidae* which, however, cannot be assigned to a definite age.

The lower part of the Barfaq section is barren; therefore we have no evidence of an Upper Cretaceous age, which however has to be considered as possible, for this stratigraphic interval.

The upper two levels, overlying the middle Palaeocene, are possibly of post-Palaeocene age, as indicated by the occurence of fragments of *Planorbulinidae,* which family is known to range from the Eocene to the Recent. Since the levels with planktonic foraminifera and with the supposed *Planorbulinidae* are practically in contact, a significant gap corresponding at least to the Upper Palaeocene should be considered.

In terms of environment, the examined samples indicate a shallow marine sedimentation, with evaporitic episodes. The fossil population is of littoral type (abundance of *Miliolidae, Melobesiae,* bryozoa, *Rotaliae*) except for planktonic foraminifera, which however are rare and present only in sample 61 AE-100/3, which comes from a marly level interbedded with gypsum.

1.7. Ambar Koh Section.

This section was measured and sampled in 1961 by E. MARTINA, and has a total thickness of about 200 m (see fig. 23, page 121). The samples submitted to a micropaleontological research are three, one of which studied

in thin sections, the remaining two washed. From bottom to top we found:

61 AE-89/1 - Impure foraminiferal biosparite with molluscan and echinoid fragments, abundant *Cibicides* and related forms, *Miliolidae,* arenaceous foraminifera, *Rotaliae* etc.

61 AE-89/2 - Washing residue poor, consistent of indisgregated arenaceous fragments, iron-ore, pyrite etc. The organic content is given by molluscan fragments, fish teeth, and abundant foraminifera. The assemblage is rich in *Lagenidae, Cibicides, Eponides* and planktonic foraminifera.

The following species have been recognized (see Pl. 6, fig. 1):

Bulimina ovata d'Orbigny
Cibicides cf. *infraferganicus* Bykova
Cibicides rigidus Bykova
Citharina sp.
Dentalina communis (d'Orbigny)
Eponides sp.
Glomospira sp.
Nodosaria cf. *latejugata* Gümbel
Robulus roemeri (Reuss)
Robulus sspp.
Spiroplectammina cf. *spectabilis* (Grybowski)
Textularia sp.
Globorotalia ehrenbergi Bolli
Globigerina microsphaerica (Morozova)
Globigerina spiralis Bolli
Globigerina aff. *spiralis* Bolli
Globigerina triloculinoides Plummer

61 AE-89/5 - Washing residue abundant, very rich in indisgregated dark red rock fragments, hyaline quartz crystals, iron ore, crystalline rock fragments, calcitic grains of probable organic origin. The fossil content is poor and not well preserved. It consists of bryozoa and foraminifera, among which arenaceous forms, *Cibicides*, *Globigerina.*

The only level from the Ambar Koh section which has a chronological significance is 61 AE-89/2, which bears a fairly rich foraminiferal assemblage with *Globorotalia ehrenbergi* and *Globigerina microsphaerica,* which is

typical for the middle Paleocene. The underlying 61 AE-89/1 level is very rich in miliolids.

The range of *Globorotalia ehrenbergi* is limited to the middle Palaeocene, for general agreement. However, this taxon should not co-exist with *Globigerina spiralis*, which species is known to disappear at the same level at which *Globorotalia angulata* first occurs. This (anomalous) co-occurrence may be due either to a local range of *Globorotalia ehrenbergi* more extended upwards than generally admitted, or to reworking. This latter hypothesis is considered improbable since the underlying section consists of shallow water deposits, quite different from those under consideration.

It is opinion of the present authors that level 61 AE-89/2 may be referred to the *Globigerina quadratoseptata* zone, even in absence of the zonal marker. This attribution is based on the occurrence of *Globigerina microsphaerica*, which first appears in the afore mentioned zone.

The lack of assemblages indicating the Upper Palaeocene and the Lower Eocene suggest a gap corresponding to the considered interval.

Non-deposition or post-depositional erosion may have caused such a gap. Megafossil faunas indicating a Middle Eocene (Alai) age are present, reworked, in association with uppermost Middle Eocene (Turkestan) faunas in the uppermost part (levels 3 and 4) of the Ambar Koh section (see Berizzi, 1970 b). The corresponding microfaunas, unfortunately, are chronologically insignificant.

In terms of paleoecological interpretation, the studied samples reveal a deeping of the sedimentary basin during Palaeocene times, while the upper part of the section, which may be referred to the Middle—Upper Eocene after its content in megafossils, but is micropaleontologically insignificant, indicates a shallow water environment.

1.8. Ali Abad Sections.

Near Ali Abad (Kataghan) in the central part of the Upper Amu Darya Depression, Martina sampled two reduced Tertiary sections which are very interesting as they bear megafossils as well as foraminifera (see fig. 24, page 130).

Section 1 represents the lower portion of section 2, and has a thickness of about 115 m. We examined two samples, from bottom to top:

61 AE-93 - Poorly washed biosparite with foraminifera and molluscan fragments, containing *Rotaliae, Cibicides, Miliolidae* etc. (see Pl. 3, fig. 3).

61 AE-94 - Washing residue consisting of fine indisgregated arenaceous grains, with quartz, iron-ore and mica flakes. The organic content is given by internal moulds of foraminifera, *Globigerinae, Anomalinidae, Lagenidae* etc.

The planktonic forms, belonging to the genera *Globigerina* and *Globorotalia*, cannot be classified at a species level. The benthonic forms include:

Anomalina toddae HARRIS & JOBE
Anomalina sp.
Dentalina sp.
Karreria fallax RZEHAK
Robulus sp.
Spiroplectammina sp.

Section 2 consists of two samples, one of which washed, the other one studied in thin section. From bottom to top they are:

61 AE-91/3 - Washing residue poor, given by numerous indisgregated, limonitized granules. The same material constitutes the internal moulds of megafossils. Quartz, feldspar, pyrite, gypsum, iron-ore are also present in the residue. The organic content is given by abundant foraminifera, not well preserved; chiefly *Lagenidae*: the genera *Robulus, Nodosaria* and *Marginulina* etc. are present with large specimens, as well as ostracods and fish teeth.

The following benthonic species are recognized (see Pl. 7, fig. 2):
Angulogerina wilcoxensis (CUSHMAN & PONTON)
Anomalina toddae HARRIS & JOBE
Gaudryina sp.
Gyroidinoides scrobiculata (CUSHMAN & PONTON)
Haplophragmoides sp.
Marginulina longiforma (PLUMMER)
Nodosaria bacillum DEFRANCE
Nodosaria bacillum minor HANTKEN

Siphogenerina sp.
Spiroplectammina sp.
Trochammina sp.
Uvigerina elongata Cole
Vulvulina sp.

The planktonic foraminifera (chiefly *Globigerina* cf. *triloculinoides*) are rare and cannot be classified owing to their poor preservation.

61 AE-91/2 - Micrite with abundant clastic quartz and rare glauconite. The organic content is rare and consists of molluscan fragments, ostracods, *Miliolidae, Rotalina* ?, etc (see Pl. 3, fig. 4).

Levels 61 AE-94 and 61 AE-91/3, belonging respectively to section I and section II, may be correlated on the basis of the benthonic foraminiferal assemblages, which are quite similar. However, only the latter is chronologically significant. The occurrence of *Globigerina triloculinoides* associated with typical Paleocene benthonic species suggest a Middle to Upper Palaeocene age. In both sections the planktonic foraminifera-bearing beds overly limestones rich in *Miliolidae.*

The clayey levels of Palaeocene age are overlain by fossiliferous beds very rich in megafossils indicating a Lower-Middle Eocene age.

Once more, a gap in sedimentation corresponding to the Upper Palaeocene (?)-Lower Eocene (part ?) is considered probable, on the basis of the available data.

1.9. Tashkurghan Section.

This section, of a total thickness of about 590 m, has been sampled and described by Desio in 1961 (see fig. 25, page 138). Our micropaleontological investigation has been carried out on seven samples, three of which were examined in thin section, the remaining four in washing residues.

The micrographic characters are as follows, from bottom to top:

61 AD-59/12 - Foraminiferal bio-intramicrosparite very rich in *Siderolites,* among which *S. calcitrapoides* Lamarck, and containing *Lepidorbitoides* sp., *L.* cf. *socialis* (Leymerie), *Orbitoides* cf. *apiculata* (Schlumber-

GER), etc. The greatest part of the orbitoidal foraminifera are in fragments. Smaller foraminifera are also present such as *Rotaliidae*, arenaceous forms and rare planktonics like *Globotruncana stuarti* (DE LAPPARENT), accompanied by molluscan fragments, *Melobesiae*, bryozoa etc. (see Pl. 5, fig. 3).

61 AD-59/11 - Foraminiferal bio-intrasparite with *Miliolidae, Rotaliidae, Cibicides* sp., arenaceous forms and also with bryozoa, molluscan and echinoid fragments etc. (see Pl. 5, fig. 2).

61 AD-59/7 - Poorly washed clayey biosparite with bryozoa, *Melobesiae*, molluscan fragments, echinoids spines and plates, small arenaceous foraminifera, some *Miliolidae, Rotaliidae*, rare *Rotalina*? and planktonic foraminifera, among which *Globigerina triloculinoides* (see Pl. 5, fig. 1) may be recognized.

61 AD-59/6 - Washing residue abundant, rich in quartz hyaline crystals, gypsum, indisgregated fragments more or less limonitized, calcite, muscovite, biotite, glauconite, green rocks fragments etc. The organic content is given by planktonic and benthonic foraminifera. The following species have been recognized (see Pl. 7, fig. 1):

Cibicides infraferganicus BYKOVA
Dentalina cf. *acuta* D'ORBIGNY
Discorbis sp.
Nonion sp.
Pararotalia heckeri (BYKOVA)
Spiroplectammina sp.
Uvigerina cf. *elongata* COLE
Uvigerina sp.
Chiloguembelina trinitatensis (CUSHMAN & PONTON)
Globorotalia traubi GOHRBANDT
Globorotalia rotundimarginata (SUBBOTINA)
Globigerina eocaena GUEMBEL
Globigerina falsospiralis (DAVIDSON & MOROZOVA)
Globigerina cf. *prolata* BOLLI
Globigerina pseudoeocaena pseudoeocaena SUBBOTINA [1]
Pseudohastigerina wilcoxensis (CUSHMAN & PONTON)

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(1) See PREMOLI SILVA (1970), foot note at page 143.

Miliolidae, Textulariidae, ostracoda, radiolaria, echinoid spines. Some reworked *Globotruncanae* and *Hedbergellae* are also present.

61 AD-59/2 - Washing residue red in colour, composed by indisgregated rock fragments (red), quartz and calcite crystals, gypsum, sometimes geminated. No organic content is noticed.

61 AD-59/1 - Washing residue very abundant, similar to the proceding one this too red in colour and barren.

61 AD-59/3 - Washing residue containing hyaline quartz grains, gypsum in laminae up to 5 mm in size, calcite, mica flakes, limonitized granules etc. The organic content is rich in fragments of molluscan shells (*Ostreidae*), echinoid spines, ostracoda, radiolaria and small foraminifera, among which:

Cibicides artemi BYKOVA
Cibicides infraferganicus BYKOVA
Eponides sp.
Nonion ex gr. *laeve* (D'ORBIGNY)
Nonionella cf. *ovata* BROTZEN
Quinqueloculina sp.
Uvigerina spinicostata CUSHMAN & JARVIS
Valvulineria iphigenia SAMOILOVA
Virgulina (?) *dibollensis* CUSHMAN & APPLIN
Globorotalia aff. *opima nana* BOLLI
Globorotalia rotundimarginata (SUBBOTINA)
Globorotalia aff. *rotundimarginata* (SUBBOTINA)
Globigerina officinalis SUBBOTINA
Globigerina tarchanensis SUBBOTINA & SHUTSIEVA.

DISCUSSION ON BIOSTRATIGRAPHY. The Tashkurghan section here considered contains some levels which are well dated micropalaeontologically: the lowest one, 61 AD-59/12, which contains a rich assemblage of orbitoidal foraminifera, associated with *Siderolites calcitrapoides* and *Globotruncana stuarti*, clearly indicates a Maastrichtian age.

The following levels 61 AD-59/11 and 61 AD-59/7, which are very similar for their microfacies, may be referred to the Palaeocene due to the occurrence, in the latter, of *Globigerina triloculinoides*.

Level 61 AD-59/6 may be referred to the upper Lower Eocene due to

the occurrence of *Pseudohastigerina wilcoxensis, Globigerina pseudoeocaena pseudoeocaena, Globorotalia rotundimarginata* etc. Though some significant species are lacking, the association may be considered typical for the zone with conical Globorotalias of Subbotina (= *G. aragonensis* zone of Krasheninnikov). In terms of tropical zonations, it may be referred to the upper part of *Globorotalia palmerae* Zone, or correspondent.

Level 61 AD-59/3 may be attributed to the upper Middle Eocene due to the occurrence of *Globorotalia rotundimarginata* and *Globigerina officinalis.* The first taxon is known to disappear at the top of the Middle Eocene, or at the top of the so called « thin walled pelagic foraminifera » zone of Subbotina, which underlies the « *Globigerinoides conglobatus* » zone, of Upper Eocene age. *Globigerina officinalis* first appears in the upper Middle Eocene and ranges through the Upper Eocene and Oligocene. The concurrent range of the two species thus is limited to the aforementioned zone which, in terms of tropical zonations, should correspond to the *Truncorotaloides rohri* Zone (= P. 14 Zone of Blow, 1969).

In conclusion, we point out that the existence of the Upper Palaeocene and of part of the Lower Eocene has not been documented in the Tashkurghan section.

Starting from the upper part of the Lower Eocene, the section is well documented with isolated microfossils or with megafossils or with their joint occurrence (see also Berizzi 1970 b).

According to the available data, it appears that the Tashkurghan section does not range to the Upper Eocene.

The reworked Upper Cretaceous specimens present in the assemblage of level 61 A-59/6 suggest that Upper Cretaceous sediments underwent erosion during the Upper Palaeocene. This fact confirm that the lack of faunas indicating an Upper Palaeocene-Lower Eocene (part) age is due to a gap in sedimentation.

The environmental significance of the studied samples indicates littoral (61 AD-59/12) to sublittoral (61 AD-59/11, AD-59/7) sedimentation for the lower part of the section, according to the limestone structures and to their organic content. Levels 61 AD-59/6 and 61 AD-59/3 indicate a more pelagic environment, in connection with a probable deepening of the sedimentary basin.

Comparison with the Tashkurghan section as described by Solun & Chepov (1963). — The examined section has been described by Solun & Chepov (1963), who found the Upper Cretaceous (Coniacian) terminating with an erosional surface and directly overlain by Palaeocene and Eocene formations as follows, from bottom to top:

a) Bukhara limestone 514 m,

b) marls, limestones and limy clays (Suzak) 334.5 m,

c) clays, sandstones and siltites (Alai) 108.9 m,

d) clays and gypsum in the topmost part (Turkestan) 85 m.

The Bukhara beds are always eroded in their topmost part, as well as the topmost Turkhestan beds.

Our level 61 AD-59/12, of clear Upper Maastrichtian age, cannot be located in the section described by Solun & Chepov, since they expressely state that the Palaeocene Bukhara limestone directly overlies deposits of Coniacian age (see op. cit., page 276).

A better location is possible for level 61 AD-59/11, which approximately corresponds to beds 3-4 of Solun & Chepov, at about the middle of the Bukhara beds. Level 61 AD-59/7 seems to correspond to the upper part of the same unit, on the basis of its lithology.

Level 61 AD-59/6 may tentatively be correlated with the upper part of the Suzak beds, though without any micropalaeontological evidence.

Level 61 AD-59/8, which is known only after its content in megafossils, belongs to the Alai beds and should correspond to level 13 of the cited authors (page 287).

Level 61 AD-59/3 is located in the clayey levels of the Turkestan beds, and particularly should be correlated with the levels described at page 290 (of Solun & Chepov), always on the basis of lithology and stratigraphic position with respect to the enclosing units.

1.10. Tentative Correlation between the Sections.

The examined sections may be tentatively correlated by means of their microfacies and/or their micropalaeontological content, as shown in fig. 26 (page 143).

We shall try to describe these correlations, beginning from the older (lower) levels, towards the younger (upper) ones:

1) The probably lowest levels here examined belong to the Qara Tut section, and are represented by sandstones, conglomerates, quartzites. These levels may be correlated with the upper part of the Karkar section described by DESIO, CITA & PREMOLI SILVA (1965), belonging to the « Red Grit » horizon. Lacking of organic content, the correlation is based on lithological analogy on the stratigraphic position with regard to level 2), which in the Karkar as well as in the Qara Tut section overlies level 1).

2) Level 61 AD-48/18 a of the Qara Tut section, level 61 AE-87/5 b of the Farkhar section, level 61 AE-77/1 of the Archa Kotal outcrop may be correlated to one another and with level 61 AP-178/34 of the Karkar section for the identity of their microfacies, which is characterized by more or less impure oo- to bio-oosparites rich in molluscan debris.

The age of this level cannot be determined directly because of the lack of significant microfossils: it is probably Lower Cretaceous and is at any rate not younger than the Cenomanian, since it underlies the *Cuneolinae-Dicyclinae* bearing level in the Forkhar section.

3) Level 61 AE-97/7 of the Pull-i-Khumri section (A) may be correlated with level 61 AE-95/1 of the Pull-i-Khumri section (B), with level 61 AD-48/18 b of the Qara Tat section, and with level 61 AP-178/35 and /36 of the Karkar section for the identity of the microfacies, consisting of sandy oosparites with a scanty organic content (small fragments of bryozoa, echinoid, molluscs, *Miliolidae*).

The age of these levels, as well as the age of the levels described in 2), is deduced indirectly by the stratigraphic position with respect to the *Cuneolinae-Dicyclinae* bearing level 5), which overlies level 3) in the Pull-i-Khumri section.

4) Levels 61 AD-30/6 of the Baba Darwes section, 61 AD-34/2 of Mohammad Aba and 61 AE-87/11 of the Farkhar section are correlative and may be considered of the same age according to their content in planktonic foraminifera (*Hedbergellae*). *H. delrioensis,* which is present in the Farkhar section, ranges from the Albian to the Cenomanian. The absence of more evolved species speaks in favour of an Albian age, which is also in agreement with

the Cenomanian-Turonian age of the overlying *Cuneolinae* and *Dicyclinae*-bearing level.

5) Levels 61 AE-95/13 bis of the Pull-i-Khumri section, 61 AE-87/12 and /13 of the Farkar section, levels 61 AD-30/3, /9, /4, /10 of the Baba Darwes section, level 61 AD-34/1 of the Mohammad Aba outcrop near Baba Darwes and 61 AD-56 of the Argana pass outcrop ([1]), may be correlated. They bear an assemblage rich in *Cuneolinae, Dicyclinae, Miliolidae, Ophtalmidiidae,* frequently also fragments of rudists, bryozoa, etc. The species *Cuneolina pavonia parva* HENSON and *Dicyclina schlumbergeri* MUNIER CHALMAS have been recognized in the Farkhar and Mohammad Aba samples. The age of this association is surely Upper Cretaceous and may be referred to the Cenomanian and possibly also, at least in part, to the Turonian. This chronological attribution is in agreement with the megafossil fauna coming from the same levels.

6) Levels 61 AD-30/3′, 61 AD-30/5 of the Baba Darwes section, 61 AD 35/1 of the Chenar-i-Gunjeshkan pass outcrop near Baba Darwes may be correlated for their microfacies and micropaleontological content. The assemblage is given by *Orbitoides, Orbitocyclina, Siderolites* and fragments of the sames. The species *Orbitoides media* (D'ARCHIAC) and *Orbitocyclina minima* (DOUVILLÉ) have been identified in the upper part of the Baba Darwes section, as well as *Siderolites calcitrapoides* LAMARCK, which is present very frequently at the base of the Tashkurghan section (level 61 AD-59/12) with *Lepidorbitoides* ssp. and *Orbitoides* cf. *apiculata* (SCHLUMBERGER).

The age of this assemblage in the whole is surely Campanian-Maastrichtian. Even if the succession cannot be controlled in all the sections, we point out that within the orbitoidal assemblage, a lower level rich in *Orbitoides* s.str.; a middle level with *Orbitoides* (often in fragments) associated with *Orbitocyclina minima* and rare *Siderolites*; an upper level with *Siderolites,* large *Rotaliae* and fragments of *Lepidorbitoides* may be recognized.

7) Levels 61 AE-100/3 bis of the Barfaq section, 61 AD-59/11 and /7 of the Tashkurghan section, 61 AE-83 of the Ali Abad section, 61 AE-89/1 of the Ambar Koh section may be correlated for the identity of their microfacies,

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(1) see page 144.

characterized by intrabiosparite rich in small *Miliolidae* and rotaliid foraminifera (large *Rotaliae, Cibicides* etc.). Arenaceous foraminifera are also present, as well as fragments of various megafossils.

The age of this microfacies cannot be directly defined, lacking of significant fossils. However, it can be defined indirectly, since it overlies the orbitoidal level of Maastrichtian age in the Tashkurghan section, and it underlies the level with planktonic foraminifera described in 8), which indicates a Middle Palaeocene, in all the sections considered (Barfaq, Tashkurghan, Ali Abad, Ambar Koh).

8) The assemblages included in level 61 AE-89/2 from Ambar Koh, 61 AE-100/3 from Barfaq, 61 AE-91/3 from Ali Abad may be correlated, on the basis of their content in planktonic foraminifera and also of their stratigraphic position, since they all overly the *Miliolidae*-bearing limestone.

Globorotalia ehrenbergi, indicating a Middle Palaeocene age, is present at Ambar Koh in association with *Globigerina spiralis* (ranging from the lower to the Middle Palaeocene); it is also present at Barfaq in association with *Globorotalia quadratoseptata,* the first occurrence of which is known to be later than the first occurrence of *G. ehrenbergi.* From the above, it results that the sample from Barfaq is slightly younger than the sample from Ambar Koh.

The correlation with the Ali Abad sample is less precise, due to the poor planktonic foraminiferal faunas. The benthonic assemblage, however, is very similar to the one found at Barfaq, so that they may be considered approximately coheval.

Level 61 AD-59/7, examined in thin section due to its calcareous lithology, yielded some specimens of *Globigerina triloculinoides,* also indicating a Palaeocene age. The stratigraphic position confirms the proposed correlation.

Samples containing isolated foraminifera indicating an age younger than those considered so far have been investigated in the Tashkurghan section alone. Therefore they are not discussed here (see page 142).

Discussion. Among the sections investigated, those measured at Qara Tut, Baba Darwes, Farkhar, Karkar, Pull-i-Khumri, Tashkurghan (part) include Cretaceous formations.

Those which are more extended downwards are characterized at the base by detrital sediments containing rare fossil fragments, such as bryozoa

and echinoids, of scarce stratigraphic significance and indicating a sublittoral environment.

A marked transgression takes place during the Albian, with the deposition of planktonic foraminiferal marls with *Hedbergellae.*

The level bearing *Cuneolinae* and *Dicyclinae,* which may be considered as a marker horizon of the north-eastern Afghanistan Upper Cretaceous, seems to close a sedimentary cycle.

The lack of fossil assemblages indicating an age intermediate between the probable Lower Turonian (*Cuneolinae*-bearing level) and the Campanian-Maastrichtian (orbitoidal foraminifera level) suggests an important hiatus or gap, which is also recorded by different authors (see WEIPPERT, 1968). The conglomerate present in the upper part of the Pull-i-Khumri section is connected to the transgression, which elsewhere is not so clearly documented.

The bryozoa-bearing levels of the topmost part of the Pull-i-Khumri section belong to the new sedimentary cycle.

The transition from the Cretaceous to the Tertiary cannot be documented in the sections investigated. Only in the Tashkurghan section both the tompost Cretaceous and the Palaeocene are present, however, due to tectonic complications and to the incompleteness of field observations, no sure statement can be made.

The sections measured at Ambar Koh, Ali Abad, Barfaq, Tashkurghan (part) include Palaeocene and/or Eocene formations.

They can be discussed both lithostratigraphically and chronostratigraphically according to the scheme proposed by the Russian authors for the region north of the Amu Darya river, where the units called Bukhara, Suzak, Alai and Turkestan have been defined.

Three horizons are distinguished by MOROZOVA, KREJDENKOV & DAVIDSON (1965) in the Bukhara beds. From bottom to top, they are:

a) Tabakcha horizon, characterized by limestones and dolomites with mollusca and foraminifera, including Miliolids, Rotaliids, *Cibicides* and *Nummulites.*

b) Aruktau horizon, consisting of marls and clays in the lower part, of limestones and gypsum in the upper part. The lower part is very rich in mollusks and planktonic foraminifera, including *Planorotalia pseudo-*

menardii [1], *Globigerina microsphaerica* (*Globorotalia quadratoseptata* assemblage); the upper part is poor in planktonic forms but it is rich in *Lagenidae, Miliolidae* and *Anomalinidae.*

c) Karatag horizon, consisting of compact clayey limestones rich in mollusks and sometimes also in benthonic foraminifera, with rare planktonics belonging to the *Acarinina tadjikistanensis* zone.

Among the sections here investigated, the basal *Miliolidae* bearing limestones may be referred to the top of the Tabakcha horizon; the foraminiferal marls correspond to and may be correlated with the lower part of the Aruktau horizon and possibly also to the upper part. We have no evidence for the Karatag horizon.

In the Barfaq section the *Miliolidae*-bearing limestone corresponding to the top of the Tabakcha horizon is underlain by a thick body of limestones practically unfossiliferous and therefore difficult to be located. These limestones possibly belong to the lower part of the Bukhara beds and also, at least in part, to the underlying Akdjar horizon (the so-called « Montian » of the Russian authors).

Always at Barfaq, the marls of the Aruktau horizon are very thin and are overlain by an erosional surface. This surface had already been recorded previously, but the present investigations allow a better understanding and definition of the hiatus. In the Barfaq section almost the entire Aruktau horizon and the Karatag horizon are lacking, and we cannot define to which unit the limestones overlying the marly level belong.

In the Ambar Koh and Ali Abad sections the hiatus is very wide and corresponds to the whole Karatag (upper unit of the Bukhara beds) and to the Susak beds. As discussed above, megafossils (mainly *Ostreidae*) characteristic of the Alai beds are present, mixed with forms typical for the Turkestan beds, in strata immediately overlying the Middle Palaeocene marls. It cannot be excluded that also the taxa indicating a younger age are reworked.

In the Tashkurghan section the upper part of the Bukhara beds are lacking, as well as (probably) the lower part of the Susak beds: the cited units are separated by an erosional surface already recorded by SOLUN & CHEPOV (1963).

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(1) *Planorotalia pseudomenardii*, identified in this horizon, probably corresponds to the *Globorotalia ehrenbergi*.

From the above it may be concluded that the stratigraphic gap existing between the Bukhara and Susak beds, previously considered to be restricted to north-eastern Afghanistan, is extended at least to central-north Afghanistan (Tashkurghan). In this latter area, however, the vertical extent of the gap is more restricted than to the east (Kataghan). Fossil assemblages characteristic of the Susak, Alai and Turkestan beds in fact are present in normal succession, while in the eastern area (see Ali Abad and Ambar Koh sections) gaps and condensations are noticed in correspondences with the aforementioned units.

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PLATE I

Fig. 1. - Sandy foraminiferal bio-intramicrite with bryozoa, *Orbitocyclina minima*, *Rotaliae*, echinoid plates etc., × 35.
Baba Darwes section, level 61 AD-30/3'.
Maastrichtian.

Fig. 2. - Impure bio-intramicrite with molluscan debris, *Cuneolinae*, *Haplophragmoides* etc., × 30.
Baba Darwes section, level 61 AD-30/3.
Cenomanian-Turonian.

Fig. 3. - Compact micrite containing elongated crystals (geminated), sometimes branched, which possibly represent autigenous anhydrite crystals, secondarily substituted by calcite, × 15.
Polarized light, parallel nicols.
Qara Tut section, level 61 AD-48/11.
Lower Cretaceous.

Fig. 4. - Quartzitic sandstone, with clastics of different size, more or less rounded. The dominant constituent is quartz. Minor constituents are tourmalin, zircon, muscovite, sericite, iron-ore etc., × 25.
Polarized light, crossed nicols.
Qara Tut section, level 61 AD-48/2.
Lower Cretaceous.

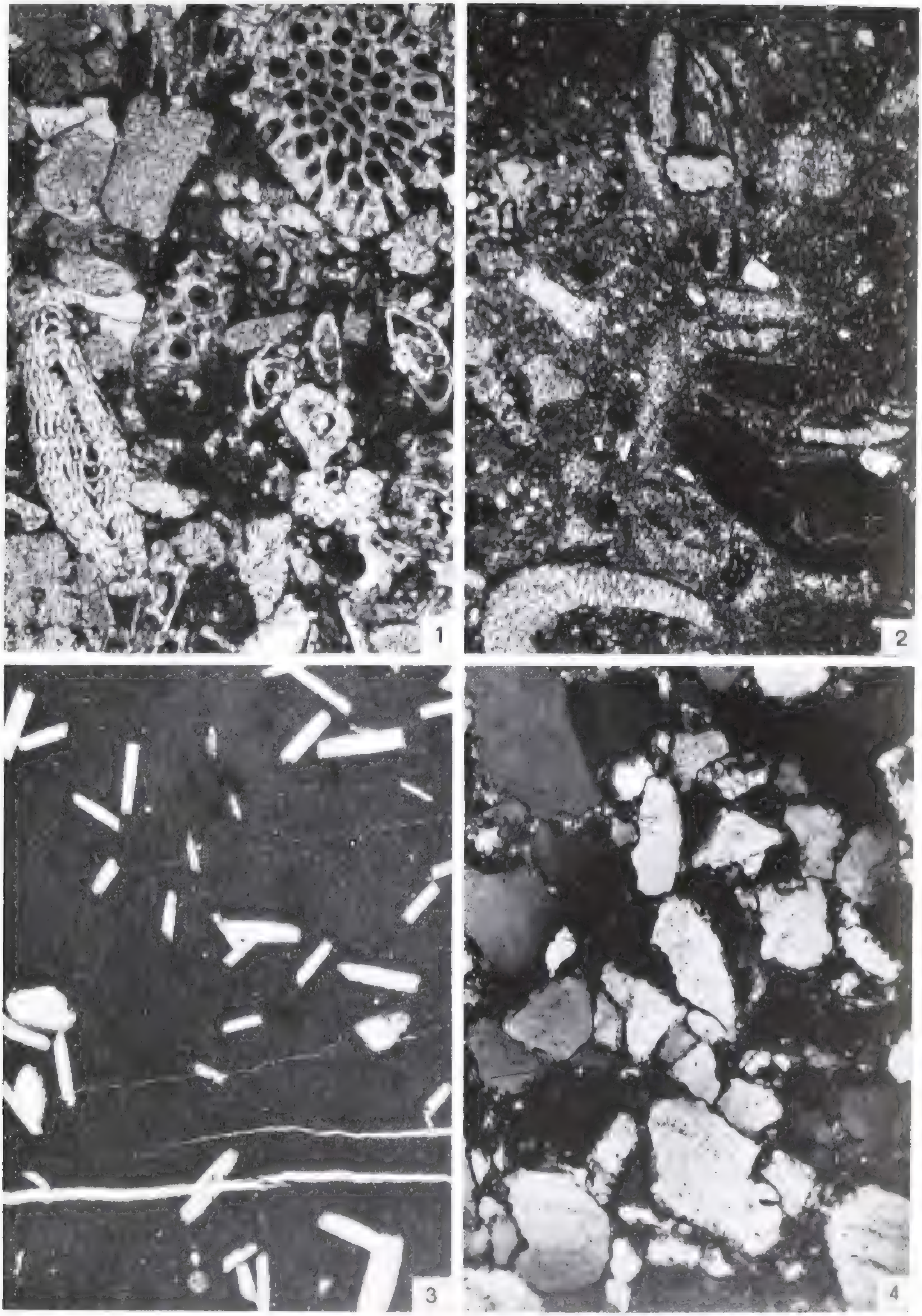
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PLATE 2

Fig. 1. - Foraminiferal biomicrite with molluscan fragments, *Cuneolinae, Lituolidae*, etc., × 50.
Farkhar section, level 61 AE-87/12.
Cenomanian-Turonian.

Fig. 2. - Sandy, fossiliferous micrite with *Hedbergella delrioensis* (Carsey), × 80.
Farkhar section, level 61 AE-87/11.
Albian (?).

Fig. 3. - Fossiliferous intramicrite very rich in bryozoa, × 12.
Farkhar section, level 61 AE-87/5b.
Lower Cretaceous.

Fig. 4. - Oosparite with shell fragments and detrital quartz, × 35.
Farkhar section, level 61 AE-87/5b.
Lower Cretaceous.

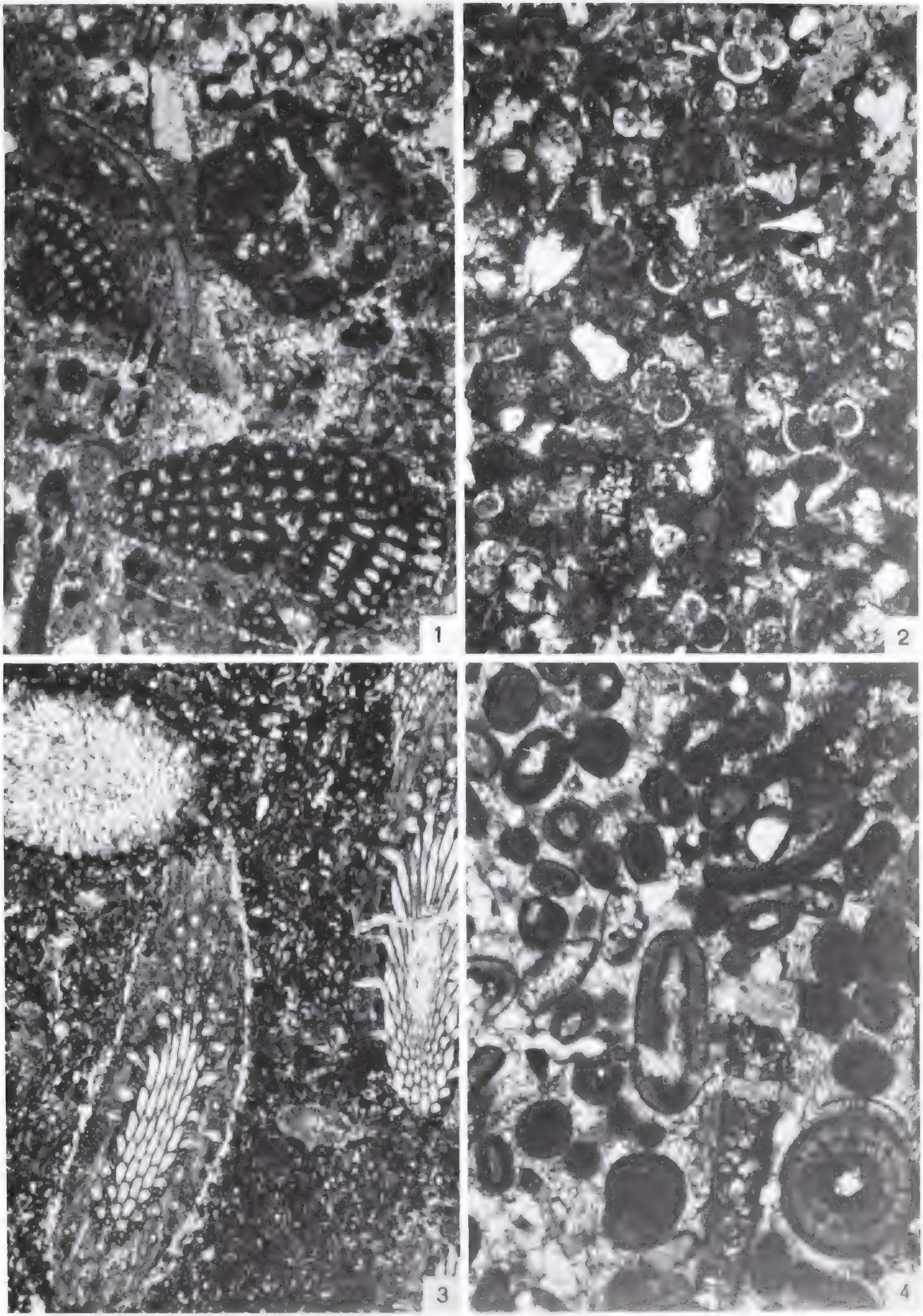
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PLATE 3

Fig. 1. - Biomicrite with *Miliolidae* (*Quinqueloculina*), *Ophtalmidiidae* (*Spirophtalmidium*), *Verneuilinidae* (*Clavulina*) etc., × 16.
Barfaq section, level 61 AE-100/5.
Probable Palaeocene.

Fig. 2. - Pelletiferous micrite with intraclasts and abundant rounded quartz grains and rare foraminifera (*Rotalia* ?), × 50.
Polarized light, parallel nicols.
Barfaq section, level 61 AE-100/7.
Probable Palaeocene.

Fig. 3. - Poorly washed fossiliferous sparite with molluscan fragments, *Rotaliae*, *Anomalinidae*, *Miliolidae* etc., × 20.
Ali Abad section, level 61 AE-93.
Middle Palaeocene.

Fig. 4. - Micrite with abundant clastic quartz. The organic content is scattered and consists of small foraminifera, among which problable « *Rotalina* », × 25.
Ali Abad section, level 61 AE-91/2A.
Middle Palaeocene.

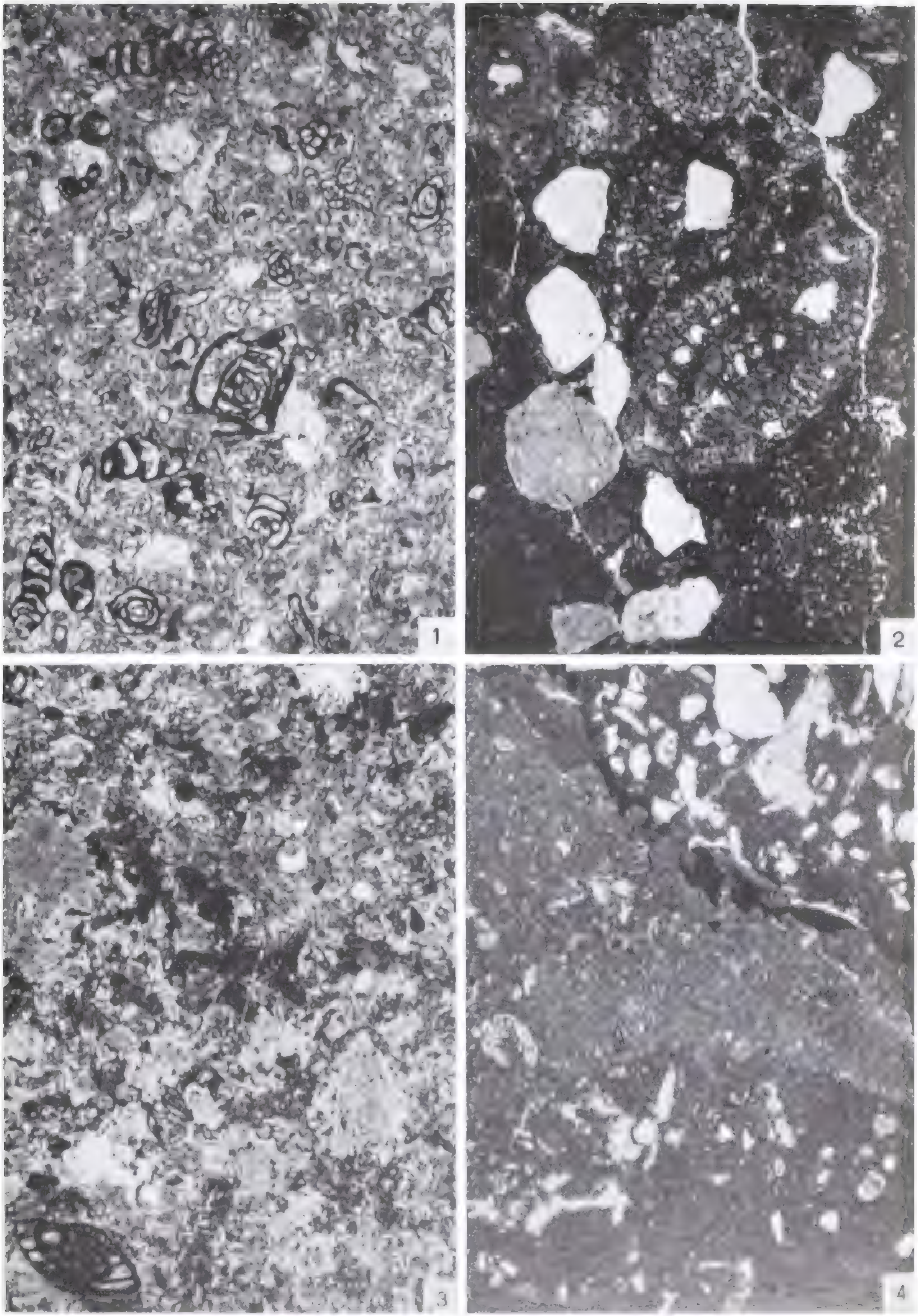
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PLATE 4

Fig. 1. - Impure dolomitized biosparite with corals, bryozoa, echinoid plates and spines etc., × 25.
Pull-i-Khumri section, level 61 AE-95/22.
Upper Cretaceous.

Fig. 2. - Sandy biomicrite partly recrystallized. The rock is extremely rich in bryozoa and molluscs. × 15.
Pull-i-Khumri section, level 61 AE-95/4.
Lower Cretaceous.

Fig. 3. - Oosparite with abundant detritic quartz, × 50.
Pull-i-Khumri section, level 61 AE-95/1.
Lower Cretaceous.

Fig. 4. - Sandy oosparite passing to orthoquartzite cemented by sparitic calcite with oolites, × 70.
Polarized light, parallel nicols.
Pull-i-Khumri section, level 61 AE-97/7.
Lower Cretaceous.

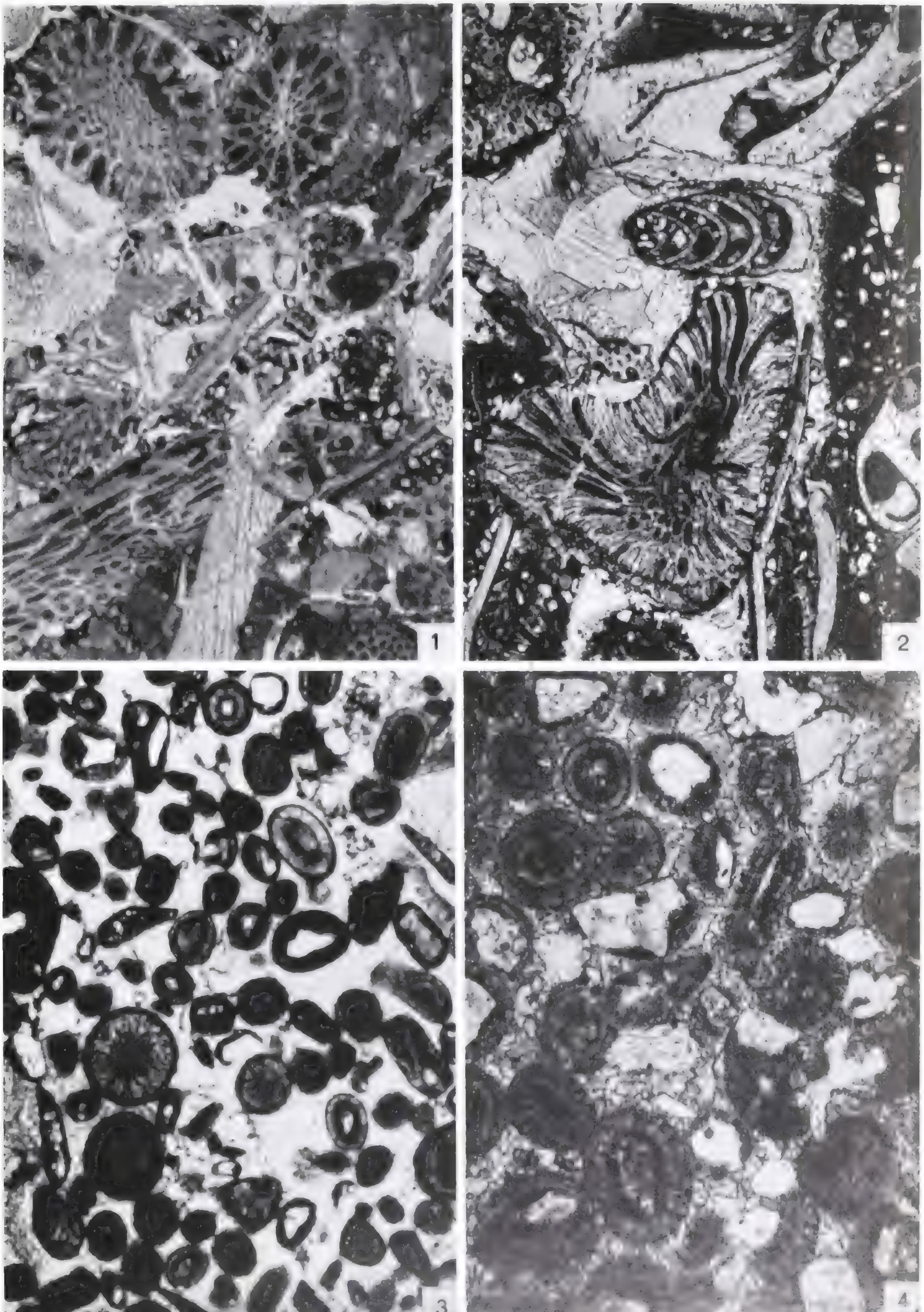
1
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PLATE 5

Fig. 1. - Poorly washed, clayey biosparite with bryozoa, molluscan and echinoid fragments etc., × 15.
Tashkurghan section, level 61 AD-59/7.
Middle Palaeocene.

Fig. 2. - Foraminiferal bio-intrasparite with *Miliolidae*, *Rotaliidae*, echinoid fragments etc., × 20.
Tashkurghan section, level 61 AD-59/11.
Middle Palaeocene.

Fig. 3. - Foraminiferal bio-intra-microsparite very rich in *Siderolites calcitrapoides* (Lamarck), with *Lepidorbitoides* and rare smaller foraminifera, × 22.
Tashkurghan section, level 61 AD-59/12.
Maastrichtian.

Fig. 4. - *Orbitocyclina*-biosparite, × 35.
Chenar-i-Gunjeshkan pass, sample 61 AD-35/1.
Maastrichtian.

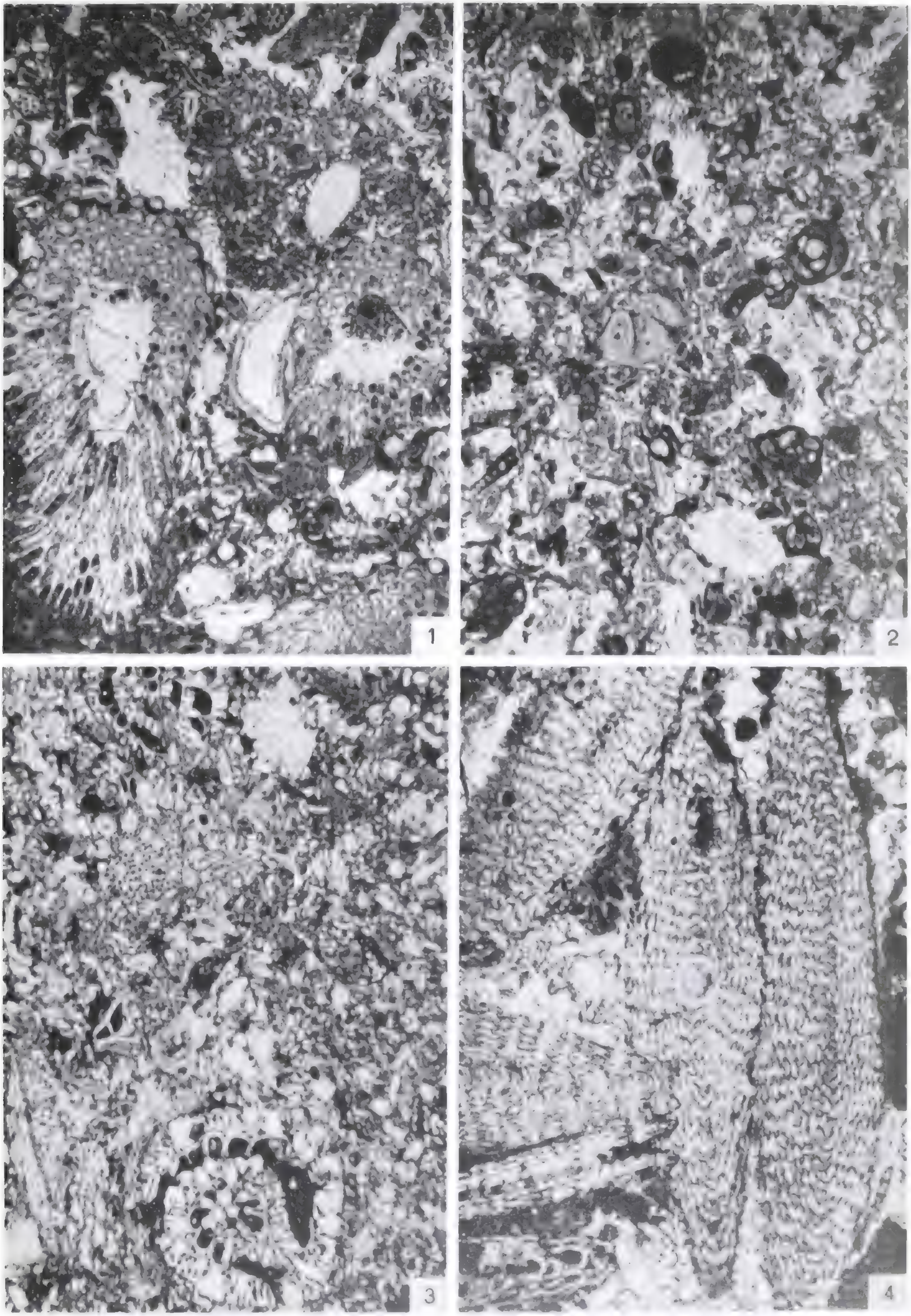
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PLATE 6

Fig. 1. - Foraminiferal association of level 61 AE-89/2, $\times$ 35.
Ambar Koh section. Middle Palaeocene.

Fig. 2. - Foraminiferal assemblage of level 61 AE-100/3, $\times$ 18.
Barfaq section.
Middle Palaeocene.

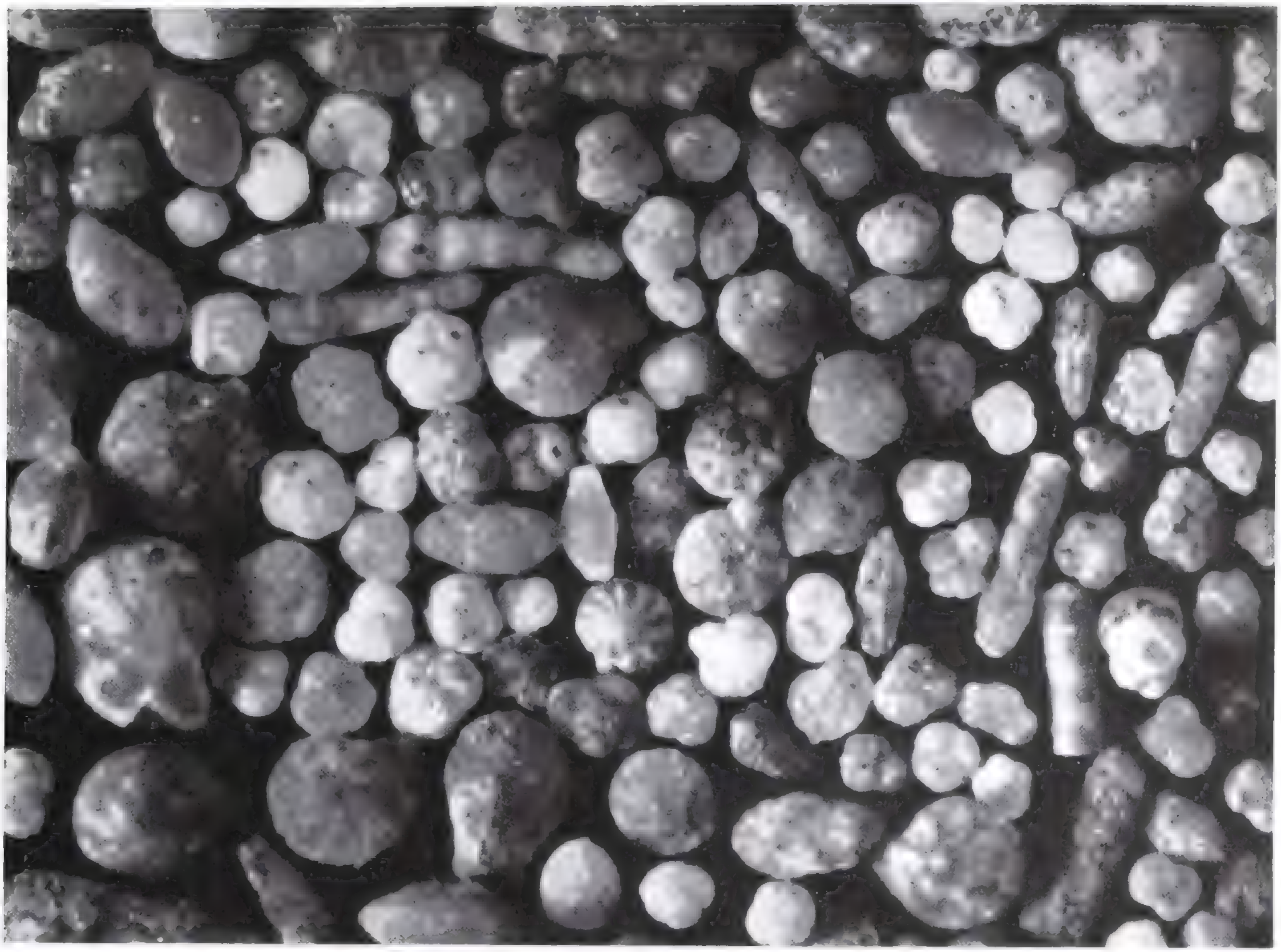

Fig. 1.

PLATE 7

Fig. 1. - Foraminifera from level 61 AD-59/6, × 45.
Tashkurghan section.
Late Lower Eocene.

Fig. 2. - A group of foraminifera from level 61 AE-91/3, × 30.
Ali Abad section. Probable Palaeocene.

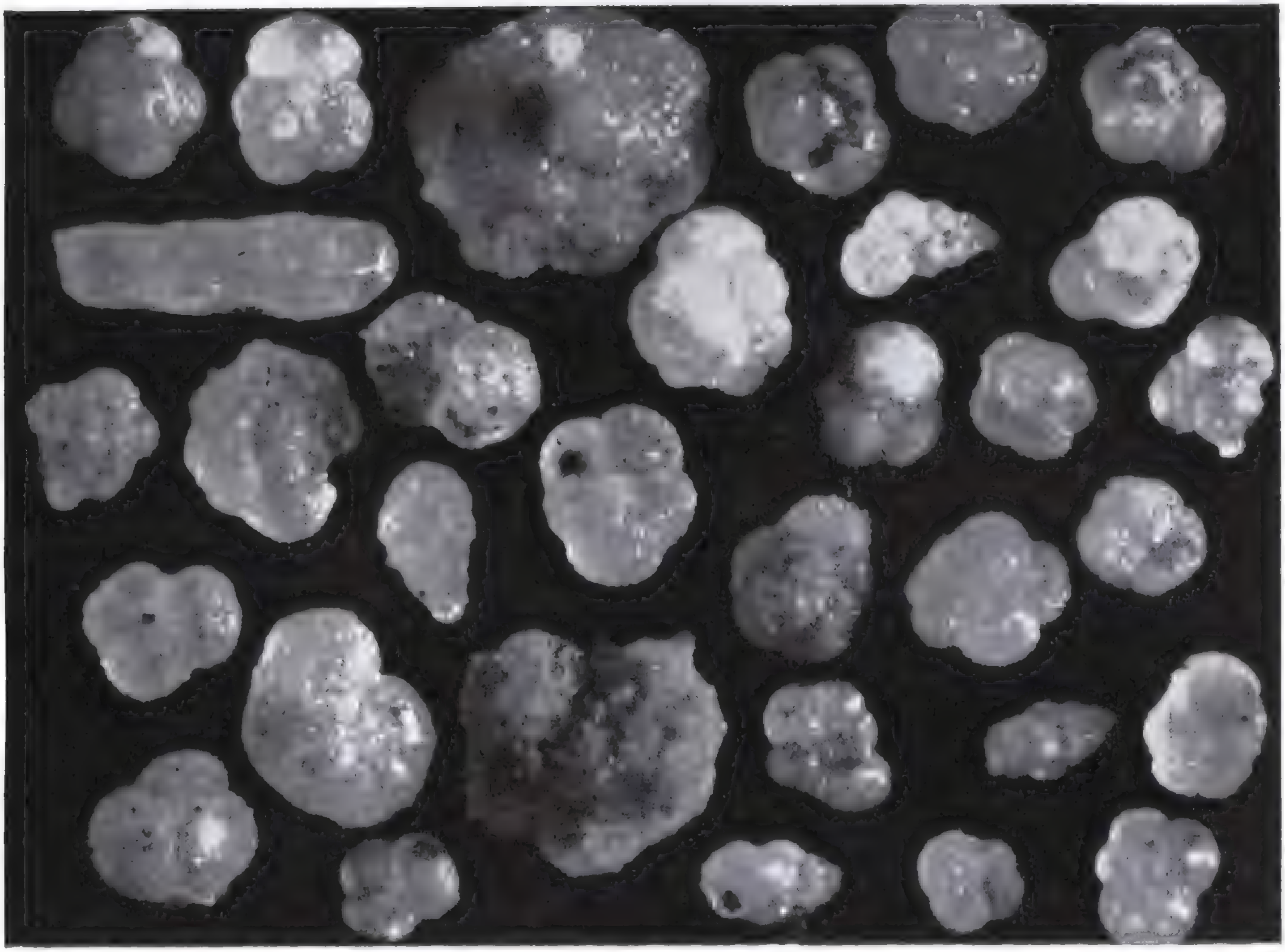

Fig. 1.

2. MEGAFOSSILS OF SOME LOCALITIES OF NORTH-EASTERN AFGHANISTAN [1].

2.1. Introduction.

Here below are brief descriptions of fossiliferous localities discovered in 1961 by the scientific expedition led by Prof. ARDITO DESIO. They are listed in order of age: from the most ancient to the most recent. The localities marked on the Geological Map of Central Badakhshan accompanying the present volume are numbered progressively from 1 to 10 (from the most ancient to the most recent). For each fossiliferous locality, besides the characteristics of the rock containing the fossils, there is a list of the species and their age. A description of the species can be found in the 2nd volume of part IV of this series.

Other fossiliferous localities were discovered in 1965 by R. VARVELLI, who sent us, for study purpose, the samples found there. Our thanks are due not only to R. VARVELLI, who brought to light the fossils from the localities mentioned in paragraphs 2.3. and 2.4., but also to the scientists who examined the large amount of paleontological material, P. D. W. BARNARD, A. BERIZZI QUARTO DI PALO, M. GAETANI, C. ROSSI RONCHETTI and A. V. SCHOUPPÉ.

2.2. Wuran Shahr Pass no. 2.

(Fossiliferous locality no. 2 on the Geological Map) (61 AFP-5). Situated 3 km north of Wuran Shahr pass, and 1 km north of height 3161, at 2820 m above sea-level, in the small valley sloping down the west side of the Kalawch valley.

Grey limestone of the Kalawch Limestone with:

Cyrtospirifer verneuili (MURCHISON)
Cyrtiopsis davidsoni barrauxensis GRABAU

(1) Summary by C. ROSSI RONCHETTI.

Camarotoechia sp.
Productella sp.

Age: Upper Devonian. Determined by M. GAETANI.

2.3. Wuran Shahr Pass no. V. 1.

(Locality not marked on the Geological Map) (65 AV-6). This locality is not marked on the Geological Map as it was discovered in 1965, that is, the year following the publication of the map (1964). Locality situated 1000 m south-east of fossiliferous locality N. 2.

Kalawch Limestone with:

Fasciculophyllum multiseptatum SCHOUPPÉ
Zaphrentites sp.ind.
Caninophyllum tomiense (TOLMACHEV)
Amygdalophyllum ? kalawchense SCHOUPPÉ
Michelinia ? sp.ind.

Age: Lower Carboniferous. Coral fauna gathered by R. VARVELLI, 1965. Determined by A. v. SCHOUPPÉ.

2.4. Wuran Shahr Pass. no. V. 2.

(Fossiliferous locality not marked on the Geological Map) (65 AV-2). Situated 3 km north of the Wuran Shahr pass, at an altitude of 2840 m above sea-level, at the confluence of two small valleys sloping down from heights 3451 (south-west) and 3630 (north-west), on the west side of the Kalawch valley. This fossiliferous locality is not marked on the Geological Map as it as discovered after the publication of the map. The locality is situated approximatively 550 m west of fossiliferous locality N. 2.

Black shale of the Furmoragh Formation, with:

Pterophyllum filicoides (Schlotheim) THOMAS
Pterophyllum kalawchiense BARNARD
Otozamites ashtarense BARNARD
Taeniopteris pseudobrevis BARNARD

Age: Upper Triassic. Plants collected by R. VARVELLI, 1965. Determined by P. D.W. BARNARD.

2.5. Wuran Shahr Pass no. 1.

(Fossiliferous locality no. 1 of the Geological Map) (61 AFP-1). On the Northern side of Wuran Shahr valley, at an altitude of 2470 m a.s.l. on the way to Wuran Shahr pass. Black microcrystalline, sometimes bituminous, often laminated limestone of the Wuran Shahr Limestone, with:

Ctenostreum proboscideum SOWERBY
Pholadomya canaliculata ROEMER
Pinna sp.

Age: Upper Jurassic. Determined by C. ROSSI RONCHETTI.

2.6. Baba Darwes no. 3.

(Fossiliferous locality no. 3 of the Geological Map) (61 AD-30 bis). On the south-eastern slope of trigonometric point 1891,7 west of Baba Darwes. Not in situ.

Brown and grey limestone of the Baba Darwes Formation with:

Trigonarca sp. ind.
Pinna arata FORBES
Pecten sp. ind. YABE
Neithea gibbosa (PULTENEY)
Pycnodonte vesicularis (LAMARCK)
Lopha sp. ind.
Arctica calabra (SEGUENZA)
Aphrodina cf. *plana* (SOWERBY)
Ichthyosarcolites triangularis DESMAREST
Ichthyosarcolites tricarinatus PARONA
Rudists and brachiopods indeterminable.

Level 6 (61 AD-30/10):

Hippurites sp. ind.

Age: Cenomanian. Determinated by A. Berizzi Quarto di Palo.

2.7. Between Darra Sarkhao and Doshi.

(Fossiliferous locality outside the Geological Map) (61 AD-68). In a locality far to the south, relatively distant from the others, in the Cretaceous Limestone called « Massive Turonian limestone » by Popol & Tromp (1954) were found:

Pycnodonte vesicularis (Lamarck)
Pycnodonte vesiculosa (Sowerby)
Cardita nicaisei Coquand
Veniella sp. ind.

Age: Cenomanian-Turonian. Determined by A. Berizzi Quarto di Palo.

2.8. Mohammad Aba (Kishem) no. 5.

(Fossiliferous locality no. 5 of the Geological Map) (61 AD-34). 1 km to the west of Mohammad Aba, a short distance away from the signpost at the border of the road, between Kataghan and Badakhshan, 1300 m a.s.l., in the Baba Darwes Formation, but from different strata, were found:

Trigonarca diceras (Seguenza)
Lima sp. ind.
Amphidonte conica (Sowerby)
Pycnodonte vesicularis (Lamarck)
Pycnodonte vesiculosa (Sowerby)
Ichthyosarcolites sp. ind.
Rudists indeterminable.

Age: Cenomanian-Turonian. Determined by A. Berizzi Quarto di Palo.

2.9. Mohammad Aba (Kishem) no. 6.

(Fossiliferous locality no. 6 of the Geological Map) (61 AD-34/1). Situated 2 km west of Mohammad Aba, on the hill north of the road, at an altitude of 1420 m, and at the top of a series of strata which outcrop there. Grey limestone of the Baba Darwes Formation, with:

Pycnodonte vesicularis (LAMARCK)
Trigonia sp. ind.
Aphrodina plana (SOWERBY)
Sauvagesia sanfilippoi PARONA
Haustator multiplicatus PCELINCEV
Pleurotomaria sp. ind.
Trochactaeon matensis (FITTIPALDI)

Age: Cenomanian-Turonian.

(61 AD-29) Locality situated slightly to the north-west of Mohammad Aba, near the preceding one. In the same formation were recognised the following species:

Lima (*Acesta*) cf. *obsoleta* DUJARDIN
Pycnodonte vesicularis (LAMARCK)
Hippurites

Age: Upper Cretaceous. Determined by A. BERIZZI QUARTO DI PALO.

2.10. Road to Farkhar.

(Fossiliferous locality no. 4 of the Geological Map) (61 AE-87/11). On spur overlooking, to the north, the turning for Farkhar on the Taluqan-Faydzabad road, at an altitude of 1400 m. Brown marly limestone of the Baba Darwes Formation with:

Amphidonte columba (LAMARCK)

(61 AE-87/13). In the same locality, in the debris, were found the following:

Amphidonte columba (LAMARCK)

Amphidonte conica (SOWERBY)
Pycnodonte vesicularis (LAMARCK)
Inoceramus sp. ind.
Thomasites sp. ind.

Age: T u r o n i a n.

(61 A-15) Locality situated in the Farkhar valley approximatively 4 km west of the road fork to Farkhar, in the Baba Darwes Formation were found:

Pycnodonte vesicularis (LAMARCK)
Echinoid

Age: U p p e r C r e t a c e o u s. Fossils gathered by E. MARTINA of the DESIO expedition (1961) and determined by A. BERIZZI QUARTO DI PALO.

2.11. Baba Darwes no. 8.

(Fossiliferous locality no. 8 of the Geological Map) (61 AD-49). West of Baba Darwes, at an altitude of 1850 m, slightly to the east of trigonometric point 1891,7.

Grey limestone of the Baba Darwes Formation, with:

Neithea (*Neitheops*) *quinquecostata* (SOWERBY)
Lima canalifera GOLDFUSS
Exogyra overwegi VON BUCH
Exogyra sp. ind.
Pycnodonte vesicularis (LAMARCK)
Rectithyris odiumensis SAHNI
Rectithyris cf. *rotunda* SAHNI
Rectithyris subdepressa (STOLICZKA)

Age: S e n o n i a n. Determined by A. BERIZZI QUARTO DI PALO.

2.12. Baba Darwes no. 9.

(Fossiliferous locality no. 9 of the Geological Map) (61 AD-35). In the western ridge of trigonometric point 1891,7 south-east of the Chenar-i-Gu-

njeshkan pass, at an altitude of 1780 m. Brown and grey limestone of the Baba Darwes Formation with:

Amphidonte decussata (GOLDFUSS)
Rectithyris subdepressa (STOLICZKA)

Age: Senonian.

(61 AD-37/1) Further to the north of the preceding locality, that is, north-west of Jeldragh, and still in the Baba Darwes Formation, was found: *Pycnodonte vesicularis* (LAMARCK), ranging from Albian to Upper Senonian. Determined by A. BERIZZI QUARTO DI PALO.

2.13. Aq Bulaq no. 7.

(Fossiliferous locality no. 7 of the Geological Map) (61 AE-69). On the northern summit of the crest sloping down to the north of trigonometric point 1804,4 3 km east of Aq Bulaq.

Grey limestone of the Baba Darwes Formation with:

Ceratostreon spinosum (MATHERON)
Arctica sp. ind.

The data are too poor for allowing exact dating of the outcrop.

(61 AD-54). Between Aq Bulaq and road fork to Farkhar, above the Kalafghan salt mine, and still in the Baba Darwes Formation, was found *Pycnodonte vesicularis* (LAMARCK) ranging from Albian to Upper Senonian. Determined by A. BERIZZI QUARTO DI PALO.

2.14 Kalafghan no. 10.

(Fossiliferous locality no. 10 of the Geological Map) (61 AE-65). On the mountain 7 km north of Kalafghan, at an altitude of 1700 m.

Grey limestone, and marl of the Bluti Formation, with:

Ostrea (*Turkostrea*) *afghanica* VIALOV
Fatina (*Fatina*) *boehmi boehmi* (VIALOV)
Fatina (*Sokolowia*) *esterhazyi esterhazyi* (Pavay, Partim VIALOV)

(61 AE-66) Approximatively 1 km west-southwest of the preceding deposit, at about 1700 m, and in the same formation were recognised:

Ostrea (*Turkostrea*) *afghanica* VIALOV
Ostrea (*Turkostrea*) *cizancourti* COX
Fatina (*Sokolowia*) *esterhazyi buhsei* (GREWINGK)

Age: Middle-Upper Eocene (Alai-Turkestan stages) Determined by A. BERIZZI QUARTO DI PALO.

2.15. Shiboglu Kotal.

(Fossiliferous locality outside the Geological Map) (61 AD-58). To the west of Shiboglu Kotal, in the Ambar Koh Formation, are contained the following species of pelecypods:

Ostrea (*Cymbulostrea*) *multicostata* DESHAYES
Ostrea (*Flemingostrea*) *schurabica* VIALOV
Ostrea (*Turkostrea*) *afghanica* VIALOV
Ostrea (*Turkostrea*) *cizancourti* COX
Ostrea (*Turkostrea*) *khaudaguensis* VIALOV
Ostrea (*Turkostrea*) *turkestanensis baissunensis* BÖHM
Fatina (*Sokolowia*) *esterhazyi buhsei* (GREWINGK)
Cavilucina (*Pegophysema*) *thebaica* (ZITTEL)
Pterolucina menardi (DESHAYES)
Diplodonta cycloidea (BELLARDI)
Corbicula veneriformis (DESHAYES)
Meretrix aegyptiaca (MAYER-EYMAR)
Meretrix incrassata (SOWERBY)
Meretrix transversa (SOWERBY)
Venus everesti D'ARCHIAC
Venus cf. *gumberensis* D'ARCHIAC
Venus sp. ind. aff. *matheroni* COQUAND

Age: Eocene, between Thanetian and Priabonian (Bukhara, Alai-Turkestan stages). Determined by A. BERIZZI QUARTO DI PALO.

2.16. Tashkurghan.

(Fossiliferous locality outside the Geological Map) (61-AD-59). In the mountains south of Tashkurghan, in in the Ambar Koh Formation, various levels yielded fossils, but the richest level was no. 9.

Level 8 (61 AD-59/1):

Ostrea (*Turkostrea*) *afghanica* VIALOV
Ostrea (*Turkostrea*) *cizancourti* COX

Level 9 (61-59/3):

Fatina (*Fatina*) *beldersaiensis beldersaiensis* (Gorizdro, partim VIALOV)
Fatina (*Fatina*) *beldersaiensis romanowskii* (BÖHM)
Fatina (*Fatina*) *boehmi boehmi* (VIALOV)
Fatina (*Fatina*) *boehmi transita* (VIALOV)
Fatina (*Sokolowia*) *esterhazyi esterhazyi* (Pavay, partim VIALOV)
Fatina (*Sokolowia*) *esterhazyi buhsei* (GREWINGK)
Venus everesti D'ARCHIAC

Level 6 (61 AD-59/5):

Ostrea (*Cymbulostrea*) *multicostata* DESHAYES
Ostrea (*Turkostrea*) *khaudaguensis* VIALOV
Ostrea (*Turkostrea*) *turkestanensis borgalensis* VIALOV

Level 7 (61 AD-59/8):

Ostrea (*Solidostrea*) *hemiglobosa* RAMANOWSKYI
Gryphaea (*Gryphaea*) *latipyga* VIALOV
Gryphaea (*Phygraea*) *tournali* (DONCIEUX)

Age:

Level 9, Upper Eocene (Turkestan stage)
Level 8, Middle Eocene (Alai stage)
Level 6, Middle Eocene (Alai stage)
Level 7, Lower Eocene (Susak stage)

Determined by A. BERIZZI QUARTO DI PALO.

2.17. Ali Abad.

(Fossiliferous locality outside the Geological Map) (61 AE-90). Samples collected not in situ, among which the following were recognised:

Ostrea (Turkostrea) afghanica VIALOV
Ostrea (Turkostrea) cizancourti COX
Liostrea (Kokanostrea) kokanensis (SOKOLOW)
Cardium halaense D'ARCHIAC

Age: Lower Eocene - Upper Eocene (Suzak-Turkestan stages). (61 AE-91/2). Samples coming from a locality 4 km from Ali Abad, in the valley which slopes down the north-west side of Koh-i-yaka Badam, in the Ambar Koh Formation. The following were identified:

Ostrea (Cymbulostrea) multicostata DESHAYES
Cardium kanleanum COTTER

Age: Middle Eocene - Upper Eocene (Alai-Turkestan stages). (61 AE-92) 8 km south of Ali Abad, in the Ambar Koh Formation, the following species were recognised:

Ostrea (Cymbulostrea) multicostata DESHAYES
Ostrea (Turkostrea) cizancourti COX
Ostrea (Turkostrea) turkestanensis baissunensis BÖHM
Diplodonta cycloidea (BELLARDI)
Cardium halaense D'ARCHIAC
Cardium kanleanum COTTER
Arctica subathooensis (D'ARCHIAC)
Arctica transversa (D'ARCHIAC)
Meretrix semisulcata (LAMARCK)

(61 AE-10/1). Sample from the preceding locality:

Ostrea (Turkostrea) cizancourti COX

Age: Eocene (Suzak-Turkestan stages). Determined by A. BERIZZI QUARTO DI PALO.

2.18. Ambar Koh.

(Fossiliferous locality outside the Geological Map) (61 AE-89/3). Level 3 of the type-section of the Ambar Koh Formation yielded:

Pterolucina mokattamensis (Oppenheim)
Pterolucina pharaonis bialata (Bellardi)
Pterolucina pharaonis pharaonis (Bellardi)
Cardium kanleanum Cotter
Arctica transversa (d'Archiac)
Meretrix semisulcata (Lamarck)

(61 AE-89/4). Level 6 yielded:

Fatina (Fatina) beldersaiensis romanowskii (Böhm)
Pterolucina pharaonis bialata (Bellardi)

Age: Eocene, from Ypresian to Priabonian (Suzak-Turkestan stages).

(61 AE-89/7). From the samples collected not in situ the following forms were identified:

Ostrea (Cymbulostrea) multicostata Deshayes
Ostrea (Turkostrea) cizancourti Cox
Ostrea (Turkostrea) khaudaguensis Vialov
Ostrea (Turkostrea) turkestanensis turkestanensis Romanoskyi
Ostrea (Turkostrea) turkestanensis alaica Vialov
Ostrea (Turkostrea) turkestanensis borgalensis Vialov
Ostrea sp. ind. Vialov
Liostrea (Kokanostrea) kokanensis (Sokolow)
Gryphaea (Gryphaea) smirnowi Romanowskyi
Gryphaea (Ferganea) sewerzowi Romanowskyi
Fatina (Fatina) beldersaiensis beldersaiensis (Gorizdro, partim Vialov)
Fatina (Fatina) beldersaiensis romanowskii Böhm
Fatina (Fatina) boehmi boehmi (Vialov)
Fatina (Sokolowia) esterhazyi esterhazyi (Pavay, partim Vialov)
Fatina (Sokolowia) esterhazyi buhsei (Grewingk)

Age: The fossils not in situ must come from different levels of the Ambar Koh Formation, since the various species identified typify different stages of the Eocene. The formation may therefore be dated without any doubt to the Eocene. An interesting point is the finding of *Gryphaea sewerzowi* Romanowskyi, mentioned so far only in the Oligocene. It seems highly probable, therefore, that the same sedimentation conditions persisted even into the Oligocene, but the limited amount of samples does not allow a definite conclusion to be reached.

Determined by A. Berizzi Quarto di Palo.

2.19. Valley to the North of Hugi Jangal (Taluqan).

(Fossiliferous locality outside the Geological Map). The samples are to be considered together with those above-mentioned because they come from the same zone, but they were collected on a different day:

(61 AD-55) The forms identified are:

Fatina (*Fatina*) *beldersaiensis beldersaiensis* (Gorizdro, partim Vialov)
Fatina (*Fatina*) *beldersaiensis romanowskii* Böhm
Fatina (*Fatina*) *boehmi boehmi* (Vialov)
Fatina (*Sokolowia*) *esterhazyi esterhazyi* (Pavay, partim Vialov)
Fatina (*Sokolowia*) *esterhazyi buhsei* (Grewingk)

Age: Upper Eocene (Turkestan stage).

(61 AD-55/1).

Ostrea (*Turkostrea*) *khaudaguensis* Vialov
Ostrea (*Turkostrea*) *turkestanensis baissunensis* Böhm

Age: Middle Eocene (Alai stage).

(61 AD-55/2).

Ostrea (*Turkostrea*) *cizancourti* Cox
Ostrea (*Turkostrea*) *khaudaguensis* Vialov

Age: Middle Eocene (Alai stage). Determined by A. Berizzi Quarto di Palo.

2.20. East of Shiboglu Kotal.

(Fossiliferous locality outside the Geological Map) (61 AD-57). On the east slope of Shiboglu Kotal, outside the zone considered, in the Ambar Koh Formation, only few forms were identified:

Gryphaea (*Ferganea*) *sewerzowi* Romanowskyi
Amphidonte galeata galeata (Romanowskyi)
Amphidonte galeata rotula (Vialov)

Age: Middle Oligocene (Sumssar stage). Determined by A. Berizzi Quarto di Palo.

B. PETROGRAPHIC APPENDIX

α. DESCRIPTION OF THE SPECIMENS OF METAMORPHIC AND PLUTONIC ROCKS FROM CENTRAL BADAKHSHAN (1).

1. METAMORPHIC ROCkS.

1.1. Faydzabad Gneiss.

61 AP-30. - Biotitic-garnetiferous migmatitic gneiss. *Way out from Faydzabad to SE.*

Quartzous-feldspathic metasome prevails over microgranular gneissic palasome.

Metasome is essentially formed by big roundish or elliptical phenocrystals of andesine 35% An, insered without apparent orientation in the rock in such a quantity that they contact with each other. They are surrounded by a microcrystalline quartzous rim and by an aggregate of small biotitic laminae that shape its border.

Biotite laminae are also poikilitically included into the feldspar together with granules of quartz and andesinic plagioclase belonging to palasome.

In smaller quantity there are potash-feldspar eyes including very corroded granules of quartz and plagioclase. At the contact with this one marked myrmekitic concretions are developed.

Quartz forms aggregates to microcrystalline rows in the interstices among the feldspathic eyes. In the transition zones, of the two types of quartz, there are medium-grained granoblastic structures in which quartz mingles with slightly altered andesinic plagioclase. Here is also plenty of biotite in large and very fresh laminae, diablastically joined, intensely pleochroic up to strong red-brown. Garnets have analogous dimension to the

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(1) By F. Forcella.

ones of the feldspathic idioblasts and sometimes perfect prismatic borders. They too, are surrounded by the quartzous microcrystalline rims, but mainly by biotitic bundles with which they are sometimes interpenetrated.

Late increases of biotite are often found in the fracture surfaces of garnets.

61 AP-35. - Migmatitic banded-augen gneiss with biotite, garnet and sillimanite. *Kokcha valley: altimetric point 1396,5 of the map.*

Regularly alternating bands of different composition, placed sub-parallelly and with lenticular espansions corresponding to feldspathic eyes are distinguished.

The schistose orientation is outlined by the presence of thick biotitic bundles mingled with column-shaped sillimanitic aggregates. Biotite and sillimanite are tightly joined to a fine quartzous aggregate with smaller quantity of plagioclase andesine 34-36% An. Along the same big roundish garnet phenocrystals including plagioclase relics and chloritized biotite are lying. Some plagioclases belonging to these zones appear as augen porphyroblasts quite saussuritized, partly filled by biotitic-chloritic felts with clearings of iron-oxides.

The sialic bands have a plagioclase with analogous composition to the preceding one, but not very altered, intensely corroded by quartz that is placed in the greatest part of these bands. They are wide levels with indented suturation.

A feldspathic contribution in form of big eyes of oligoclase-andesine 30% An plagioclase with albitic twinning seems to coexist with this phase.

61 AP-37. - Augen-banded migmatite. *Kokcha valley: 500 m downstream from Kanga.*

The rock is made up of calcphyres bands with diopside, scapolite, hornblende and titanite and sialic beds prevailingly formed by ortoclase.

Calcphyres have a light equigranular granoblastic structure with prevalence of calcite and scapolite over the other components. In it the granulations of iron oxides and the limonitic pigmentations are abundant.

The sialic beds have a central part entirely made up of ortoclase crystals ($2V = -62^\circ$ $N_p \wedge (001) = 6^\circ$ in granoblastic heterogranular aggregates, per-

fectly consolidated with each other and partially covered by a light alteration patina and a marginal part where quartz appears. This part becomes a microgranoblastic rim with prevailing quartz, sometimes placed in films with undulating extintion. Near the contact small quartz patches join the calcphyre texture. Quartz forms in the feldspathic aggregate small euhedrals with mirmekitic concretions.

Inside the sialic bands there are groups of crystals of diopside, hornblende and titanite of much greater dimentions than the ones in the calcphyres. In these zones scapolite is absent and calcite is limited to a few late uncomformable veins.

61 AP-41. - Migmatitic gneiss with biotite, amphibole and scapolite. *Kokcha valley: upstream from Kanga.*

The rock presents a schistose gneissic texture with granular bands with plagioclase, quartz, amphibole, and scapolite lepidoblastic beds with biotite, and concordant veins with quartzous-feldspathic composition. The gneissic bands have prevailing granoblastic structure with quartz and plagioclase 90-92% An in granules of small and greater dimension among which the other components are distributed in different zones.

There are enrichment zones in green hornblende and titanite, zones with biotite lamellae scattered in the sialic contexture, biotitic-amphibolic zones where biotite is gathered in lepidoblastic beds, while the dimensions of the laminae increase. These beds thicken at the contact with quartz-feldspathic bands and enrich in scapolite; also hornblende has greater idiomorphism and some pyroxenic crystals appear. There is so the passage to metasome in discontinuous bands and lenses rather distant from one another. The greatest part of them is formed by quartz in big sutured levels, sometimes including small corroded parts of palasome.

There are also potash-feldspar eyes that, at the quartz contact of the gneissic bands, have marked myrmekitic rims.

61 AP-42. - Migmatitic garnetiferous gneiss poor in mica. *Kokcha valley: upstream from Kanga.*

The prevailing part of the rock is a microgranoblastic aggregate made up of quartz and orthose in quite equivalent quantity, and of oligoclase in smaller quantity.

The homogeneity of this aggregate is only broken by some garnet idioblast and by few iso-oriented laminae of green-brown biotite. Other contiguous zones present a base aggregate of oligoclase plagioclase partially sericized with scarce medium-grained quartz clearly distinct from the one of the zone with potash feldspar.

Among the micaceous elements are scarce muscovite and chlorite. There are also quartzous concordant strips with undulating extinction passing to potash-feldspar lenses, sometimes formed by a single idioblast, sometimes by groups of polygonal smaller crystals.

61 AP-43. - Calcphyre with scapolite, hedenbergite, hornblende and titanite. *Kokcha valley: gully upstream Kanga.*

A base mass of calcite and scapolite includes pyroxene granoblasts, hornblende and scattered titanite granules.

Calcite and scapolite are generally grouped in patches with homogeneous composition furnished with a banded disposition and seldom mingled with each other.

Among the coloured elements hedenbergitic pyroxene is rather diffused ($2V = 68°$; $N_g \wedge (001) = 49°$) with not very noticeable pleochroism from light-brown to pale grass-green, with idioblasts up to centimetre dimensions.

Hornblende is in late genesis at the margin and inside the greatest hedenbergitic elements, with imperfectly formed crystals, sometimes in form of bands or flakes. It is distinguished from pyroxene on an intense bottle-green colour.

61 AP-44. - Amphibolite. *Gully upstream from Kanga.*

The rock has granoblastic equigranular and homogeneous structure.

The essential components are plagioclase and hornblende in equivalent quantity.

Quartz is a rather scarce additional component. Titanite, zircon and iron-oxides are abundantly scattered.

Hornblende appears in good prismatic sections endowed with a sensible orientation of C axes, with marked pleochronism N_p = yellow-green, N_m = olive-green, N_g = brown-green.

Other optical features: $2V = 82°$, $N_g \wedge C = 17°$.

Plagioclase often develops its cleavage borders though it is clearly anhedral as to amphibole. It is made up of labradorite 64-66% An.

61 AP-45. - Migmatitic garnetiferous augen gneiss. *Kokcha valley: below the altimetric point 1603 of the map.*

A palasome of two micas gneiss is clearly distinguishable by a feldspathic metasone with remobilization of quartz and neoformation of garnet.

The gneissic portions show a marked orientation of the micaceous lepidoblastic aggregates, in which big laminae of red-brown biotite prevail. They also contain rather dismembered and incomplete garnetiferous porphyroblasts.

Near the merely micaceous bands there are very quartzous gneissic zones with scarce granules of andesine plagioclase 35-37% An and small biotite laminae in scattered isooriented order.

Quartz sometimes forms long stripes or lenses optically unitary, produced by increase and optical iso-orientation of former granules of the gneissic contexture. This quartz includes alignments of biotitic laminae without disturbing the previous orientation. The feldspathic eyes, often of great dimensions, are formed by plagioclase andesine 40% An.

They only partially develop their clearing borders, poikilitically include much corroded quartzous elements and fresh biotite films, present frequent albitic interlamellar segregations.

Their augen form is more marked by the plastic deformations of the aggregates at their contact.

61 AE-28. *Paragneiss. Sum Darrah: right hand slope, 2240 m a.s.l.*

It is a distinct granoblastic mass with fine-homogeneous grain. Calcite granules prevail, quartz and plagioclase ones are in smaller quantity. Above all in the calcite there is a marked iso-orientation of the granules with consequent partial consolidating of them. As detrital elements also feldspathic sandstone and pegmatites appear, some of them have cm dimentions.

There are also many prismatic neoformed diopside crystals ($2V = +54°$, $Z \wedge C = 39°$), augite ($2V = +56°$, $Z \wedge C = 40°$) and titanite.

61 AE-29. - Amphibolic gneiss. *Sum Darrah: right hand slope, 2250 m a.s.l.*

Rocks of blastic, not much oriented structure, with medium-coarse grain variable in the different places, made up of labradorite 54% An, biotite, hornblende and quartz.

Rather marked paracrystalline deformations are noticeable mostly in the sialic elements.

61 AE-30. - Amphibolite. *Sum Darrah: right hand slope, 2280 m a.s.l.*

Rock with granoblastic equigranular structure, with cornubianitic look.

Green hornblende ($2V = -84°$, $Z \wedge C = 18°$) and anortite 96% An are here mingled in equivalent quantity.

There are also in smaller quantity diopside granules that are generally isolated and readsorbed by anortite.

61 AE-31. - Amphibolite. *Sum Darrah: right hand slope, 2280 m a.s.l.*

The rock presents a granoblastic structure dominated by crystals of rather variable dimentions of green-brown hornblende ($2V = 90°$, $Z \wedge C = 22°$) including abundant roundish granules of titanite and with scattered interstitial granulations of opaque minerals probably ilmenite.

An anortitic plagioclase (95-98% An) is scattered in isolated polygonal crystals in the amphibolic contexture.

Some leucocrate veins are made of anortite, scapolite and diopside.

61 AE-33. - Migmatitic augen gneiss with biotite, garnet and sillimanite. *Immediately to the west of Khan-i-Awrvala.*

Rock with very marked schistose texture, with feldspathic eyes and garnetiferous porphyroblast of macroscopic dimentions.

The structure is lepido-granoblastic. Huge biotitic-sillimanitic bands alternate with sialic ones made up of quartz and plagioclase andesine 33-35% An. There are patches of iso-oriented biotite laminae wholly wrapped in quartz remobilized in form of big bodies with roundish or lobed borders, often elongated in form of ribbons.

1.2. Rabat Gneiss.

61 AP-46. - Biotitic-garnetiferous gneiss with sillimanite. *Kokcha valley, NW of Rabat.*

Quartz and plagioclase form a mass with very fine regular grain and granoblastic structure.

In some zones there are long ribbons of optically unitary quartz with strong undulating extinction, accompanied with fine recrystallization at the margin. In the granoblastic mass quartz is very limpid and lacking in mechanical deformations.

Plagioclase corresponds to andesine, not much altered, in small equidimentional often well geminated crystals. There are also some plagioclasic porphyroblasts of analogous composition with a rim of incipient saussuritization.

Biotite is scattered everywhere both in small tabular laminae and in long lepidoblastic iso-oriented bundles with undulating trend among which microgranular fibrillar and column-shaped sillimanite aggregates are placed. Garnet appears with some crystals with polygonal border interrupted by the conglobating of quartz and feldspar granules and by biotite laminae.

As additional elements there are titanite and iron oxides.

61 AP-47. - Migmatitic muscovite garnetiferous paragneiss. *Kokcha valley, NW of Rabat.*

In a schistose contexture, with the composition of a garnetiferous paragneiss with muscovite, there is the subsequent introduction of feldspathic beds and eyes.

Palasome presents a granoblastic aggregate of acid andesine and quartz crossed by long and thick lepidoblastic muscovite bands, to which scarce biotite pleochroic laminae yellow-green and green-brown coloured are joined.

In the micaceous beds big garnet idioblasts are abundantly laid. The feldspathic metasome appears in big augen elements placed in a discordant way too, in relation with the previous schistose orientation. Some of them are placed in glomeroblasts and sometimes they are aligned in beds along which there is a little remobilization of the quartz.

Feldspar has the composition of andesine 31-32% An, often with fine crossed clearings (001) and (010) and albite geminations.

61 AP-48. - Marble with phlogopite and amphibole. *Kokcha valley, NW of Rabat.*

The prevailing mineral is calcite in aggregate with mosaic structure and medium grain.

The crystals are generally limpid, with neat marks of clearing and gemination. The reciprocal contacts often show a fine indenting to which also a turbid granulation is joined.

There are some thin bands filled with microgranular calcite, of earlier generation that the last crystallization, in association with actinolite and single flogopite. In these bands calcite is clearly increased with amphibole that appears in de-fibred incolour crystals.

On the contrary, phlogopite is extremely fresh, pleochroic, incolour to straw yellow or brown-reddish, both in lamellar aggregates and in isolated tabular sections, generally increased at the margin of the great calcitic prisms.

These last are scattered outside the schistose bands and placed without preferential orientation.

As additional minerals there are apatite and small titanite prisms.

61 AP-96. - Fine-grained biotitic paragneiss. *Khash valley, NW of Jurm.*

Schistose contexture given by isolated biotite lamellae rather abundant. Bottom mass of granoblastic quartz with clastic-psammitic residual form and with plenty of potash-feldspar and albite granules. The first is partially substituted by muscovite. Uncomformable veins with cataclastic quartz partially recrystallized, kaolinized cataclastic feldspar, well formed chlorite in twisted laminae and calcite.

Additional elements: apatite, magnetite, zircon and titanite.

61 AP-97. - Band with scapolite, actinolite, diopside, and titanite in fine biotitic paragneiss. *Khash valley NW of Jurm.*

Granoblastic mass of scapolite, in rather big equidimentional crystals, de-fibred prisms of actinolite in smaller quantity, scarce diopside, lozenge-shaped sections of titanite scattered everywhere.

61 AP-98. - Migmatitic banded augen gneiss with biotite, garnet and sillimanite. *Khash valley, NW of Jurm.*

Palasome is formed by a gneissic rock analogous to the sample 61 AP-46, made up of oligoclase-andesine 28% An, totally recrystallized granoblastic quartz, wide bundles of very fresh pleochroic biotite, microgranular and fibrous sillimanite felts, a few garnet idioblasts.

Locally there are feldspar elements partially filled with muscovite laminae. Muscovite takes a chequered shape, with the meshes partially filled with feldspar.

A clear sialic addition is given by plagioclase porphyroblasts and quartzous-feldspathic lenses and bands inserting in metasome, partly moving and partly including it. Plagioclase is an acid oligoclase 16-20% An, in rather fresh crystals with nice albite twins.

Porphyroblasts are moderately idiomorph with quartzous granules and very corroded biotite relics included.

Quartz-feldspathic aggregates are made of single large specimens gathered in flooring aggregates in which metasome relics are evident also in form on thin granulations and micaceous beds.

61 AP-99. - Fine-grained biotitic paragneiss. *Khash valley, NW of Jurm.*

The rock is formed by a mass with granoblastic structure of quartz, feldspar and mica, interrupted by thin quartzous beds iso-oriented along a marked schistose texture.

Granoblastic quartz appears in specimens of small dimensions, very limpid, as the one of the iso-oriented beds is characterized by a strong undulating extinction and by the lack of individual crystals. It is an aggregate increased, probably at expenses of the pre-existing cataclased crystals, and not fully recrystallized.

Feldspar is formed by oligoclase-andesine, of analogous dimension than quartz, sometimes sericitized, scattered in proportion of 1:2 in relation with the last, without orientations or particular gatherings.

Mica is partly made up of tabular biotite laminae, furnished with regular and marked orientation, generally isolated, seldom gathered in lepidoblastic bundles or in radiate aggregates. Pleochronism is rather marked from straw-yellow or brown to brown-reddish very marked.

Muscovite is a secondary component that appears in rather irregular thin laminae along preferential beds, mainly at the contact with quartzous ribbons.

Another secondary component is formed by actinolite prisms fractured or partially substituted by biotite of a light-green colour without pleochroism. They too, are along some beds concordant ith schistose orientation. As additional minerals there are many titanite granules and small magnetite sticks and interstitial fillings in the granoblastic mass.

Some fractures are full of calcite and lamellar aggregates of chlorite rows intersecating the schistose trend of the rock at right angle.

61 AP-100. - Amphibolic gneiss and calcphyre bands with scapolite. *Khash valley, NW of Jurm.*

The rock presents a thick alternance of thin bands of gneiss and calcphyre compenetrating with each other at the contact and forming chaotic zones with microbrecciated look.

The gneissic bands are mostly made up of andesine 33-35% An, in crystals of rather changeable dimentions and that often show the marks of deep mechanical deformations. Among them, in smaller quantity there are microcrystalline quartzous aggregates, that underwent deformations after a phase of intense recrystallization.

There are also anhedral yellow-greenish very pleochroic patches made up of quite chloritized hornblende. They are often placed along microfractures partially filled with iron-oxides and calcite, near the calcphyre bands. An additional component much diffused is titanite.

Calcphyres present a mass of fine and homogeneous granoblastic calcite containing some big calcitic specimens in form of flat relics oriented along the direction of the bands forming the rock; plastically deformed and with marked undulating extintion.

In the calcareous mass there are also plently of scapolite idioblasts often grouped in thick gatherings with medium-grained floor structure, joined to hornblende and recrystallized calcite.

The contact between gneissis and calcphyres bands is outlined by iron-oxides gatherings and by a more abundant development of titanite.

61 AP-101. - Saccharoid marble with iron minerals. *Khash valley NW of Jurm.*

The rock is wholly made up of calcite with floor coarse structure with interstitial filling of iron minerals.

The calcite crystals up to centimetre dimensions, are very limpid and bear very neat marks of clearing and gemination, this one sometimes bent. The borders of the granules are clear, neatly prismatic concretion indentings are seldom noticed. Along them and along the clearing passes, column-shaped prisms of magnetite are inserted, scattered everywhere abundantly. There are also scarce titanite granules closed into calcitic specimens.

61 AP-105. - Migmatitic biotitic-amphibolic gneiss. *East of Shahran.*

The rock is formed by a fine-grained granoblastic mass of quartz, plagioclase, biotite and hornblende penetrated by a quartzous-feldspathic metasome.

Palasome looks like a gabbroid rock with a plagioclase of high basicity corresponding to bytownite 75-85% An, always present with beautiful polysynthetic twins as albite or albite-pericline. They often include quartz granules, probably coming from gneissic palasome.

Hornblende is abundant in prismatic sections tightly grown with quartzous-feldspathic metasome. They are olive-green coloured, not very pleochroic, often joined to biotite. Biotite is scattered everywhere in smaller quantity than amphibole, in laminae without orientation.

Quartz of late genesis is grouped in beds formed by very limpid crystals, with plane extintion, with big dimentions, up to 0,5 cm. Quartz of this generation poikilitically includes rather big portions of metasome, intensely corroding the sialic components mainly. Quartz itself is limited to the portions in beds beyond which it has limited diffusion.

61 AP-106. - Migmatitic augen gneiss with biotite. *East of Shahran.*

The rock is formed by granoblastic quartzous-feldspathic levels with scarce mica and sialic, mostly feldspathic glomeroblasts. In the granoblastic levels, there is plently of feldspar, formed by orthoclase and a plagioclase of medium acidity, corresponding to andesine 35° An, in the same measure.

Quartz is allotriomorph in relation with feldspars and is often placed in roundish granules outside them. Mica is given by small tabular biotite laminae without orientation and by scarce chlorite. Prevailing component of glomeroblasts is orthoclase. It appears in wide specimens with irregular borders, covered by a light patina of kaolin alteration and crossed by gaps partially filled in sericite. Strongly corroded and sometimes fully included into the feldspar some augen poikiloblasts are noticed. They are made of plagioclase with analogous composition to the granoblastic aggregate, and full of quartzous drops.

61 AP-125. - Diaftoritic garnetiferous micaschist. *In the valley upstream from Sela-i-Kalan.*

It is a rock with marked lamellar schistosity, formed by thick lepidoblastic muscovite bundles.

Among them there are quartzous stripes showing an old cataclasis partially restored, felt-shaped sericitic aggregates in form of eyes, thin chloritic beds with nematoblastic look, interlamellar clearings of limonitized iron-oxides.

Garnet appears if form of nodules made up of separated granules, of quartzous patches and of biotite partially transformed into chlorite. At the contact with the granules the lepidoblastic boundles of muscovite show passages to biotite.

61 AP-134. - Garnetiferous paragneiss. *Floor of the valley upstream from Palang Darrah.*

A quartzous granoblastic aggregate fully recrystallized with much indented and lobed margins, and marked undulating extinction is here prevailing.

Feldspar is formed by some granules of oligoclase isolated in the quartzous mass, distinguishable in it for some thin trail of polysyntetic gemination and for a thin alteration patina.

Among the micas the most diffused is biotite, in tabular pleochroic laminae, straw-yellow to brown-greenish, often containing small zircon granules, inserted without orientation in the interstices of the quartzous aggre-

gate. Muscovite in similar form to biotite is not very abundant; sometimes the awo minerals form small diablastic aggregates.

Along some beds, richer in feldspar, muscovite appears in wider fresh laminae, also bent, as metablastic component made in later phase. There are also a few garnet prismatic crystals.

As additional minerals there are a few apatite granules and iron oxides.

61 AP-159. - Fine arenaceous calcschist with scapolite. *Near Sar-i-Hauvidz.*

Fine granoblastic structure slightly oriented.

Prevailing component is calcite in crystals with polygonal borders, sometimes with clastic form, or as fine cataclastic granulation. Some zones show a more intense crystallization with orientation of the bigger crystals in bands conformable with the schistose orientation. In the zones with fine-grain there is an argillous-limonitic intergranular film that thickens in laminae conformable with the schistosity.

Among the elements with sure detrital origin, quartz in small granules with the borders sometime increased with calcite, or round-shaped, prevails. Plagioclase granules are scarce. Magnetite granules are rather diffused.

Into this fundamental mass some scapolite idioblasts with the borders partly increased with calcite, partly prismatic are noticed. The biggest of them are dismembered by big gaps filled by calcitic microgranulations. Near them there are sometimes grawing muscovite lamellae.

61 AP-161. - Bands of biotite augen gneiss, and rock pyroxene, scapolite, amphibole, and titanite bearing. *East side of Kotal-i-Dar Khan.*

The gneissic bands are formed by a regular medium-grained floor aggregate of crystals of quartz, oligoclase andesine 28-30% An and orthose with many plagioclase porphyroblasts and glomeroblasts with analogous compositon as hosts. These include strongly corroded quartz and orthoclase. Many tabular biotite laminae are scattered in diffused but iso-oriented order. A band with gabbro-dioritic composition appears near the preceding one. In it there is an abrupt increase of the grain and plenty of green hornblende appears. In the sialic part oligoclase-andesine crystals prevail. They

are isometrical and often poikiloblastic because of the inclusion of quartz roundish granules.

Also hornblende, though more idiomorph, is shaped at the borders of the quartzous granules of earlier generation.

There are also bands with scapolite, uralized pyroxene, amphibole titanite, plagioclase, poikiloblastic and recrystallized quartz.

They often present the typical structure of cornubianites, with marked idiomorphism of scapolite and xenomorphism of plagioclase, the poikiloblasts of which are sometimes rather big and with augen form.

Quartz is partially remobilized and placed in veins sub-concordant with the schistose orientation.

Some thin veins of microcrystalline quartz intersecate all the above described bands indistictly.

61 AD-13. - Fine-grained paragneiss with biotite and garnet. *5 km upstream from Tergeran (Warduj).*

A medium fine-grained rock with a granolepidoblastic texture. It has a schistose and clearly banded texture, which is emphasised by the iso-orientation of the mica aggregates. A second arrangement of planes of schistosity exists, less apparent than the first, and transverse to it. The sialic part is made up of small aggregates of quartz, with an undulatory extinction and with sutured margins, sometimes joined in extended bands with a leptinitic texture. Associated with the quartz are plagioclase crystals, often twinned and of an albite-oligoclase composition. Large poikiloblasts of garnet are scattered in the section, they include crystals of quartz with a clear extinction. This fact, and the arrangement of the bands of leptitinic quartz around them, indicate that the crystallization of the garnet is subsequent to the dynamic phenomena which caused the compression of the rock.

61 AD-15. - Biotitic amphibolite. *About 3 km downstream from Tergeran (Warduj).*

A rock with a nematoblastic texture, passing to lepidoblastic, with an orientation which is not very apparent, and is emphasised only by a slight iso-orientation of the small micaceous flakes. Amphibole of the hornblende

variety (c: γ 10-23°) is the most abundant costituent, followed by biotite and plagioclase of a composition 50-70% An (andesine-labradorite). The plagioclase is crystallized in the interstices left by the other minerals, and shows saussuritic alteration.

1.3. Kara Mughul Gneiss.

61 AP-50. - Calcphyre with quartzous feldspathic bands. *In the valley between Cakolc and Tolbuzanak.*

The rock presents a rather complex granoblastic structure, with a moderate orientation.

Prevailing calcphyres zones with big feldspathic granules and quartz-feldspar zones are distinguishable, but there is no sharp limit between the two.

Calcphyres are essentially made up of spathic calcite with paracrystalline deformations, scapolite, pyroxene (salite) and titanite.

Green hornblende appears in subordined quantity.

There are marked unhomogeneities in the distribution of these components specially of calcite that is grouped in beds and veins with variations in the granulometry of the elements, often including much corroded granules, roundish and deformed of quartz and feldspar.

Also scapolite gives rise to enrichment in granoblastic bands often with calcite cement.

The sialic bands are formed by anhedral specimens of quartz, labradorite 65-66% An and potash-feldspar, among which microcline.

All these components underwent paracrystalline deformations, thickly interpenetrating with one another and sometimes increased with elements of calcphyres, mainly with calcite and pyroxene.

61 AP-52. - Biotitic garnetiferous paragneiss. *In the valley between Cakolc and Talbuzanak.*

It is a regular grano-lepidoblastic aggregate of quartz, feldspar and biotite, with garnet granules diffused in moderate quantity.

Quartz appears both in polygonal sections and in sutured lenses and levels with undulating extintion.

Feldspar corresponds to andesine plagioclase 34-35% An and has a form not different from quartz, both of them are quite lacking in alterations.

Red-brown biotite, intensely pleochroic, is placed in an homogeneous way with groups of very iso-oriented laminae accompanied by thin interlamellar strips of ilmenite.

Garnet is made up of small granules with polygonal borders, very fresh, scattered with no relation with the other components.

61 AP-52. - Amphibolic gneiss. *1 km W-SW of Talbuzanak.*

It is an amphibolic gneiss very rich in andesinic plagioclase, 44°-45° An forming a fine-grained floor contexture together with a subordered quantity of quartz. In this contexture there are small elongated prismatic crystals of hornblende with marked pleocroism (N_p = light green, N_m = straw-yellow, N_g = blue-green), both isolated and grouped in thin beds that are seat and rectilinear.

As additional minerals there are small granules of magnetite and apatite.

61 AP-58. - Amphibolic albitized gneiss. *On the south side of Zyrat-i-Kwaja pass.*

The prevailing structure is heterogranular granoblastic, with floor aggregate rather fine and homogeneous of quartz and plagioclase with amphibolic and plagioclasic porphyroblasts as hosts.

The form of plagioclase inclines to idiomorphism that is developed mainly in the specimens of bigger dimensions. Near them other big plagioclase specimens with analogous composition (andesine 40% An) are developed. These ones, on the contrary, are as borders of the floor aggregate and include some of its crystals poikilitically. These specimens are intersecated by a thick net of microfractures oriented and filled with a feldspar with low index of refraction, optically positive, corresponding to albite.

Albite itself is inserted among the twinning lamellae and along the clearing planes of the plagioclasic xenoblasts intruding also the fractures intersecanting quartz and the intergranular gaps of the floor aggregate.

In concomitance there is the development of sericitic oriented lamellae in the plagioclases, the amphibole corresponds to a pleochroic hornblende with N_p = light yellow, N_m = green-light yellow, N_g = light green, in prismatic crystals of very changeable dimensions, sometimes in small granules associated with a few crystals of epidote, titanite, and magnetite.

61 AE-1. - Biotitic-garnetiferous paragneiss. *West of Faydzabad.*

Regular grano-lepidoblastic structure, with fine-medium grain. The rock is mainly formed by quartz, sometimes with undulating deformations, and by andesine not zoned xenoblasts imperfectly geminated.

Biotite appears in discontinuous beds, but with large and fresh laminae.

Garnet is scarce and with small dimensions. Ilmenite is abundant.

61 AE-3. - Biotitic paragneiss. *Near Absiti.*

In a granoblastic contexture of quartz and plagioclase andesine, there are a few iso-oriented laminae of biotite.

61 AE-13. - Biotitic epidotic blastomylonitic gneiss. *Near Itarci-i-Bala.*

Quartz is placed in lenses and microgranoblastic oriented stripes among big brocken and bent crystals.

Fine granules of epidote are scattered in the mylonitic contexture. Biotite is in ragged and bent rows, with rather altered laminae.

61 AE-15. - Gneissic blastomylonite. *West of Kuri.*

The rock is formed by a fine quartz-biotite mass mixed with alteration products of feldspars including big roundish relics of andesine plagioclase with marked bends in the gemination planes.

There are also sinuous rows of micro-granoblastic quartz.

1.4. Halqa Jar Amphibolite.

61 AP-53. - Slight schistose amphibolite. *Above Deh Mianah.*

The rock is characterized by plagioclasis-amphibolic aggregate in which bigger amphibole idioblasts come into evidence.

In the aggregate, with medium-grain, in equivalent proportions there are mingled a very fresh plagioclase, often geminated, sometimes zones corresponding to andesine 47% An and hornblende in prism with rows of small granules. These rows have iso-orientation, in conformity with the light schistose texture of the rock. They have perfect crystalline form, with marked pleochronism: N_p = light green, N_m = green-yellow, N_g = blue-green, in which there are frequent inclusions of ilmenite.

The interlamellar segregations of iron oxides are frequent.

61 AP-54. - Epidotic amphibolite. *Southern side of Zyarat-i-Kwaja pass.*

The rock has an unhomogeneous distribution of sialic parts with scattered granules of epidote and amphibole and only amphibolic parts. The structure changes from fine-flooring in the sialic zones to coarser granoblastic and oriented in the amphibole zones.

In the light zones the only sialic component is a plagioclase with medium basicity (andesine) among the specimens of which there are small hornblende granules and beautiful elongated prisms, perfectly idiomorph and colourless of clinozoisite ($N_g \wedge (001) = 14°$). At the contact with the amphibolic zones, clinozoisite becomes more frequent and is quite lacking inside the zones themselves. In them hornblende has great development in thickly compenetrated specimens with some orientation of the C axes.

Granulations of magnetite are frequent.

61 AP-55. - Actinolitic schist with diopside and sialic lenses. *Southern side of Zyarat-i-Kwaja pass.*

The prevailing part is formed by sub-idiomorph actinolite prisms diablastically intertwisted, thickly interpenetrating with one another, endowed with some orientation at zones. Among them isolated diopside granules are inserted. They have anhedral indented borders fringed along clearing planes. There are also granoblastic feldspathic lenses made up of a plagioclase anortite 90-92% An.

Epidote and zoisite prisms are joined to the feldspar.

In the short passage zones to the feldspathic lenses some big epidote crystals develop into the amphibolic aggregate.

61 AP-64. - Amphibolite with sialic bands. *Southern side of Zyarat-i-Kwaja pass.*

The rock is formed by the alternating amphibolitic and quartz-feldspar bands.

Plagioclase has analogous composition in the zones and corresponds to andesine 32% An. In the amphibolitic zones it is in polygonal small shaped granules, in the sialic ones it forms a floor aggregate of wider limpid crystals geminated as albite and albite - pericline. The plagioclasic aggregate of the sialic bands includes small roundish granules of quartz They are placed also inside the feldspathic crystals. Forms of graphic concretion are noticed too. As feldspar is often interested by post-crystalline deformations, quartz is lacking in it. In the amphibolitic zones quartz is absent.

Amphibole is represented by very elongated hornblende prisms with intense olive-green and yellow-green colour, not very pleochroic, associated with titanite and zircon granules.

61 AP-112. - Fine slightly schistose amphibolite. *Near Darel.*

The composition is similar to the sample 61 AP-53.

Here there is a smaller more homogeneous grain, and a more regularly oriented distribution of the amphibolic prisms.

61 AP-113. - Migmatitic rock. *400 m upstream from Darel.*

Metasome has a prevailing part in the rock with plagioclase crystals of very variable dimensions, confusedly compenetrating and pushing the preceding feldspathic elements to the borders. It is andesine 47-49% An, rather turbid with frequent geminations, but imperfectly formed and subsequently brocken or bent, sometimes poikilitic for intrusions of homblende and plagioclase belonging to palasome.

This one has a composition similar to the former that can have been changed during the last intense recrystallization it suffered.

To plagioclase of palasome plenty of green hornblende is joined.

It is transformed into rags and de-fibred relics or granular trails at the borders of neosomatic porphyroblasts by the corrosion caused by the sialic addition.

61 AP-114. - Calcphyre with pistacite, paragasite and garnet. *Near the mill, 2 km south of Muzung.*

Calcite forms a wide and homogeneous medium-grained floor aggregate. In it amphibole, epidote, garnet and iron-oxides are scattered as fine granulation or irregular aggregates.

Quantitatively an epidote of pistacite type prevails. It has strong inclined dispersion, yellow-brown colour, not pleochroic.

The form is finely granular but sometimes there are well-shaped crystals with a good clearing (001). Amphibole is represented by tabular idiomorph prisms of small dimensions of pargasite, colourless at the borders, and progressively coloured towards the centre where intense pleochroism is noticed in the following colours: N_p = yellow-greenish, N_m = emerald-green and N_g = blue-green.

The pargasite crystals are joined to the epidote ones but in smaller quantity. Garnet corresponds to a term of the grossularite-andradite, brown pale rose coloured, in strongly dismembered porphyroblasts and crystalloblastically increased with calcite. A granulation of iron oxides that show crystals with cubic or hexagonal shape is also scattered.

61 AP-123. - Actinolitic-epidotic schist partially serpentinized. *Mead of Sela-i-Kalan valley.*

Big actinolite fibrous crystals, with gaps and folds, ending in shape of flames, are into a felt aggregate of thin actinolitic fibres and antigoritic patches.

Some zones show abundant epidote. Serpentinization goes on inside the amphibolic crystals along the gap zones and outside. Just some iso-oriented lamellae following axis C are the relics of some big crystals. They have unitary optical characters, among which the laminae of antigorite increase in normal trend to them. The external shape of the crystals is mucc deformed, generally lanceolate. The felt surrounding them made up of a very compact aggregate of small antigoritic lamellae of which thin fibrillous bundles remain. They have sinuous trend of actinolite. Epidote appears among serpentinuous felt in fine granules rather turbid, gathering to form wide floor aggregates.

61 AP-124. - Actinolitic schist. *Near of Sela-i-Kalan valley.*

The rock is quite completely made up of actinolite in different form.

There is a very compact microgranular aggregate, composed of small tabular prisms, passing to fibrillous bundles folded or placed in form of rose. In it big column-shaped lanceolated prisms are placed in oriented bundles. At the contact between the two zones there are tufts of lanceolated elements of intermediate dimensions.

Rather seldom nests of incipient serpentinization appear in form of antigoritic patches.

61 AP-127. - Fine-grained amphibolite. *2 km NE of Sela-i-Kalan.*

It is a type showing prevalence of amphibole on feldspar, both of them in form of xenoblasts placed in homogeneous aggregate. Feldspar is an oligoclasic plagioclase generally lacking in geminations, often with sutured patches with irregular borders. Amphibole corresponds to markedly pleochroic hornblende in the following colour: N_p = grass-green, N_m = olive-green, N_g = blue-green. Its form is quite tabular prismatic, but it is often intruded by plagioclase. A thick granulation of zircon, apatite, or magnetite is scattered everywhere and poikiloblastically included into essential components.

61 AP-132. - Massive amphibolite with sialic spots. *Near Deh-i-Tagab.*

There is a rather irregular feldspathic contexture overlying amphibolic patches made up of specimens of different dimensions without orientation.

The feldspathic mass is prevailingly made by fine floor aggregate of crystals of andesine 48-50% An containing anhedral poikiloblasts of a more acid, oligoclasic plagioclase, riddled with acicular oriented prisms of zoisite and irregularly dotted for variations in the composition, and alteration zones in sericite. Amphibole is formed by green hornblende not very pleochroic the prisms of which, of different dimensions, sometimes very big, gather in diablastic aggregates mingling just at the margin with the feldspathic aggregate. Titanite is an additional very diffused element.

61 AP-133. - Zoned amphibolite. *Near Palang Darrah.*

The rock is composed of amphibole and plagioclase mingled in different form and proportions in thickly alternating beds.

The thickest beds present an homogeneous mixture of amphibole and plagioclase in quite equivalent quantity, having magnetite and titanite granules as abundant additional components. In this fine-grained aggregate anhedral plagioclase is given by oligoclase and amphibole by yellow-green not ver pleochroic hornblende in small idiomorph prisms. With an increase in the dimensions of the hornblende crystals there are exclusively amphibolic beds with rather marked interstitial segregations of magnetite.

1.5. Kurkhu Gneiss.

61 AP-92. - Migmatitic biotitic-garnetiferous gneiss. *Kurkhu valley, near the confluence of a right river.*

The rock presents a rather heterogeneous structure with sialic involved bands plunged into a fine-grained schistose matrix. The sialic contexture is made up of roundish plagioclasic and augen crystals of different size, covered by a diffused kaolinic patina and imperfectly geminated and by glomeroblasts of ortose, oligoclase and pertite with myrmekitic concretions.

Their composition is the one of oligoclase 28% An, twin Albite ala. Quartz is in two different forms: an older one in granoblastic aggregates with isolated specimens with polyhedric borders, generally fractured, another of later crystallization in sutured patches in thick indentings gathered in elongated bundles often in the same way of the micaceous bands. These have tortuous form with sudden expansions given by patches of wide tabular laminae and following gatherings in fibrous rows of microlamellae made turbid by iron-oxides, and partially chloritized. In the expansion zones there are garnetiferous porphyroblasts. A rather frequent additional element is zircon.

61 AP-93. - Migmatitic augen gneiss with biotite, garnet and sillimanite. *Kurkhu valley, 3320 m a.s.l.*

There is a distinct palasome of fine biotitic-chloritic gneiss and a following feldspathic contribution accompanied with recrystallization and increase of biotite and neoformation of garnet.

In palasome quartz is intensely recrystallized and moved along the schistosity planes in form of concordant bundles of sutured patches enclosing a smaller quantity of acid plagioclase. Biotite and chlorite, form in these zones an irregularly oriented boundle of fine laminae. In this contexture there are feldspathic porphyroblasts of different dimensions, made up of oligoclase 25% An seldom geminated as Albite ala, slightly altered, enclosing small myrmekitic zones and often with a rim of albitic composition. To it ortose and pertite crystals are associated in smaller quantity. Together with the growth of porphyroblasts there is the increase of micaceous lepidoblastic beds with big fresh laminae of biotite, microgranular aggregates of sillimanite and garnetiferous porphyroblasts of exceptional dimensions, with partial substitution by chlorite.

61 AP-94. - Migmatitic diaftoritic gneiss. *Middle Kurkhu valley.*

Principal features are an intense lamination and a diaftoritic alteration with kaolinization of feldspars and chloritization of biotite.

The lamination appears along oriented planes that generally bend at the contact with feldspathic porphyroblasts, marked by a total chloritization of biotite and by an intense cataclasis of quartz, with subsequent partial blastesis. The feldspathic porphyroblasts, of prevaling oligoclasic composition, and with a smaller quantity of orthose, compressed among micaceous beds took augen forms up to lanceolated as they are lacking in deformations for fracture. Their kaolinization appears in spots with variable entity, sometimes very intense.

61 AP-95. - Ortogneiss with biotite. *Lower Kurkhu valley.*

It is a massive, medium-coarse grained rocks that looks like a diorite.

It is formed by plenty of roundish porphyroblasts of oligoclase, by wide patches of quartz passing in the contiguous porphyroblasts to a micro-

granular aggregate. The additional elements are made up of lamellar rather curled groups of biotite shaped at the borders of porphyroblasts, by chlorite of secondary formation and some titanite granules.

1.6. Tarang Gneiss.

61 AP-84. - Granodiorite gneiss. *Left side of the Warduj, in front of Ushkan.*

The rock shows a slightly oriented texture of the micaceous components, rather scarce in the total composition. It is a very sialic term, rich in quartz and plagioclase, with smaller quantity of potash-feldspar.

Plagioclase appears in a group of roundish granules aligned as the schistose texture, strongly corroded by quartz and easily substituted by potash feldspar. Their composition is oligoclase 28% An. Quartz forms wide patches with minor sutured elements, endowed with marked undulating extinction. It shows gathered corrosion borders in comparison with feldspars and marked graphic and myrmekitic concretions. Potash-feldspar forms anhedral crystals of variable size that sometimes substitute plagioclase and often include quartzous nests. Micas are exclusively made up of green very pleochroic biotite in isolated laminae or gathered in short discontinuous beds.

61 AP-85. - Amphibolic gneiss. *Left side of the Warduj valley in front of Ushkan.*

The granoblastic structure is rather homogeneous with slight preminence of the sialic components on the femic ones.

A very regular aggregate made up of plagioclases of medium basicity (andesine) partially euhedral, sometimes zoned and of quartz in smaller granules and aggregates with marked undulating extinction similar to cataclastic lying in sub-oriented lenses also in association with mafic elements, is prevailing. Among the dark minerals there is hornblende with the following pleochronism: N_p = yellow-brown, N_m = bottle-green, N_g = bright green, in short prisms, with well developed rhomboidal sections. To them beau-

tiful tabular laminae of pleochroic biotite straw-yellow and olive-green coloured, very much oriented are joined. Biotite itself, without or with scarce hornblende, forms dark lepidoblasts beds made up of iso-oriented groups of fresh and big laminae.

61 AP-86. - Migmatitic gneiss. *Right hand side of the Zardew valley, near Kurkhu village.*

A quartzous crystalloblastic aggregate including feldspathic porphyroblasts of various entity is noticeable. Micas are in subordinate quantity.

Quartz appears in sutured beds locally oriented, passing to granoblastic patches of variable granulometry. After a phase of intense cataclasis, quartz appears remobilized and partly totally recrystallized, in persisting stress conditions. In it very turbid feldspathic granulation of uncertain determination are noticeable. Porphyroblasts are formed by potash-feldspar and oligoclase (17-18% An $2V = 86°$) with host antipertitic inclusions of orthose. All the feldspars appear much corroded by quartz and filled with crystalline quartzous nests very limpid and with no deformations.

Micas are given by a few lamellar groups with ragged borders, of green-brown coloured biotite.

Scarce additional minerals are apatite, titanite and iron oxides.

61 AP-87. - Microgranodiorite. *Right hand side of the Zardew valley, near Kurkhu village.*

In this rock is noticeable a fine ipidiomorph granular structure to which a regular quartz-feldspathic aggregate and plently of mafic elements contribute.

The sialic components are represented by quartz and plagioclase in quite equivalent quantity, and by potash feldspar in smaller quantity. Plagioclase is composed of crystals, sometimes euhedral, of acid andesine of slightly bigger size than the others. Quartz is marked anhedral, much corroded by feldspar and with marked undulating extinction. The mafic minerals appear with plenty of chlorite and green hornblende, placed both in scattered way and in groups in form of oriented trails. An additional element rather frequent, is titanite. There are also apatite granules.

61 AP-158. - Migmatitic plagioclasic augen gneiss. *Right hand side of the Zardew valley near Pejuje Yabad.*

In a schistose-nebulitic very micaceous texture, characterized by irregular distribution of the sialic elements, big feldspathic eyes are inserted.

The gneiss mass is prevailingly made up of plagioclases of medium acidity, with variable dimensions and shapes, with evident mechanical paracrystalline deformations. The granules of potash-feldspar are scarce. Quartz appears in sutured patches formed by partial crystalloblastesis after intense cataclasis, placed along the borders of the feldspatic granules, or as filling of microgaps, obliquely oriented with relation to the schistosity. Biotite forms lepidoblastic aggregates rather discontinuous, with quick deviations and breacks at the contact with the feldspathic crystals of bigger dimensions, that appear grown afterwards.

The augen inclusions appear as composed of glomeroblasts made up of big plagioclasic specimens intimately increased, including quartzous drops with analogous composition with the surrounding gneissic mass.

61 AD-8. - Gneissic granodiorite. *Warduj valley: few kilometres from Ushkan.*

A rock with a hypidiomorphic granular texture of medium-coarse grains, with an orientated texture, emphasised by the micas, among which biotite is the most common. The biotite is sometimes arranged in polygonal arcs. The quartz is predominant, and has an undulatory extinction. It is often in a myrmekitic intergrowth with the oligoclase (20-30% An). The oligoclase is also present as individuals without inclusions, and is sometimes twinned. Large poikiloblasts of garnet are present, and together with apatite and zircon form the accessory minerals of this rock.

1.7. Orthogneiss.

61 AP-79. - Migmatitic augen orthogneiss with biotite. *Near Ardar.*

The rock presents a fine granular portion essentially plagioclasic full of wide quartzous patches and by plagioclase porphyroblasts with more acid composition, included afterwards.

The fine granular mass presents an andesinic plagioclase that seems partly recrystallized in granoblastic way. It is reduced in narrow strips among the porphyroblasts of metasome and partially filled by patches of biotitic laminae of neoformation placed without orientation. A quite continuous biotitic border sorrounds the porphyroblasts. These show two following generations of which the first is made up of zoned specimens of andesine 33-35% An, with medium size, interested by post-crystalline deformations and a second with plagioclase of analogous composition in crystals of very big dimensions, not zoned, more limpid and with no deformations.

61 AP-80. - Biotitic orthogneiss. *Blocks of the Ardar landslide.*

Medium-grained rock rather oriented very rich in feldspars also in augen parphyroblasts and with discontinuous biotitic beds. Among the feldspars there is little potash-feldspar and much andesine 33% An, in an aggregate of anhedral granules of variable dimensions. Quartz appears in wide fractured patches, in granoblastic aggregates of later crystallization and in myrmekitic concretions with plagioclase along the contact margins with the potash-feldspar. The lepidoblastic beds of biotite, endowed with orientation, are shaped at the borders of the feldspathic porphyroblasts. Also isolated tabular laminae of neoformation without orientation are present.

61 AP-82. - Migmatitic augen orthogneiss with biotite. *Upstream from Dashtek.*

The rock differs from sample 61 AP-79 only in the presence of potash feldspar in the fine anhedral aggregate forming palasome.

61 AP-102. - Augen orthogneiss with biotite. *Darrah-i-Khash valley.*

The rock is prevailingly made up of potash feldspar and quartz in smaller quantity by plagioclase.

The mafic elements are formed by lamellar groups of green biotite partly chloritized and by abundant titanite prisms. In the sialic part fine granoblastic groups of microcline and quartz are placed in zones oriented among bigger quartzous patches mingled with microcline xenoblasts and a few sub-idiomorph crystals, generally of medium-large size, of acid oligo-

clase 20-23% An. Microcline also appears in big augen porphyroblasts including oligoclase granules with more acid border of albitic composition.

61 AP-108. - Migmatitic gneiss with muscovite and garnet. *Upstream from Naw Abad.*

In a quartzous feldspathic microgranoblastic aggregate roundish and augen porphyroblasts of microcline are included.

Micas are only in few discontinuous beds of muscovite with some biotite laminae, associated with garnet and epidote granules.

The microgranoblastic aggregate is made of microcline, quartz, thickly grown in graphic micropegmatitic forms, and by oligoclasic plagioclase. Porphyroblasts, made up of microcline with perthitic clearings of albite, cause the deflection and the mould on them of the microgranoblastic aggregate and the mafic beds. It is also recognizable quartz of early generation in cataclastic anhedral patches, with undulating extinction, much corroded and included by microcline.

61 AP-142. - Migmatitic gneiss with biotite. *On the pass between Ghala Darrah and Modrel.*

A quartzous feldspathic micaceous metasome and a neosome in feldspathic porphyroblasts is recognizable.

As in sample 61 AP-108 metasome is anhedral microganular filling of the gaps among porphyroblasts. It is made up of a fine mingling of potash-feldspar in which microcline and oligoclase are visible. They grew with small quartzous drops.

Quartz separately forms some granoblastic aggregates with medium grain and marked undulating extinction. To metasome, we have described, fibrous sericitic felts are mingled with rows biotite laminae mainly at the margin of porphyroblasts or inside them. Porphyroblasts are formed of andesine 34% An innerly grown with microcline patches.

61 AP-143. - Biotitic-amphibolic-epidote orthogneiss. *On the pass between Malmunj and Darrah-i-Razan.*

The rock is formed by a grano-lepidoblastic oriented contexture of feldspar, quartz, biotite, amphibole and epidote.

The granoblastic structure of the sialic components is everywhere homogeneous except a slight inclination to idiomorphism of plagioclase. Also the dimension of the elements, corresponding to medium grain is uniform. The composition present plagioclase (andesine 43-45% An) frequently zoned and with beautiful Albite and Albite-Carlsbad geminations, then quartz in elongated patches and segmented stripes with undulating extinction, and in smaller quantity microcline nests. Quartzous drops are included into the feldspars after their crystallization. The mafic beds rather considerable and continuous are composed of biotite in big fresh and pleochrois tabular laminae, green hornblende partially biotitized, epidote in prisms parallel to the schistosity or as scattered granulation, titanite, ferriferous segregations.

2. SEDIMENTARY ROCKS AND RELATED PARAMETAMORPHIC.

61 AP-72. - Microcrystalline dolomitic limestone. *Above Pa-in-Shahr.*

Rock formed by a fine aggregate of calcitic granules with scattered dolomite rhombohedra.

Some small quartzous clastic elements are present. Also calcite partially keeps an original clastic form.

61 AP-73. - Microcrystalline micaceous limestone with scapolite. *East of Pa-in-Shahr.*

The rock is formed by a calcitic contexture with fine granoblastic structure with detrital quartzous granules as hosts, seldom made up of acid plagioclase, partially recrystallized in floor nests.

Elsewhere there are quartz spots in patches mingled with a sericitic felt from which some muscovite laminae with albite nests come into evidence. In the calcareous contexture there are some scapolite granules. The rock is pigmented by a limonite scattered mainly as intergranular film.

61 AP-74. - Crystalline limestone with scapolite and flogopite. *Like 61 AP-73.*

The prevailing mass is given by an aggregate with fine grain partly with mosaic flooring, partly with wide spathic crystals, with diffused intergranular limonitic pigmentation. Detrital quartz in small granules is irregularly scattered. There are also scapolite porphyroblasts with perfect prismatic form, of great size too, and patches of hexagonal laminae of flogopite with pleocronism N_p = colourless, N_m = light yellow N_g = yellow-rose.

61 AP-75. - Crystalline limestone with cordierite, scapolite and flogopite. *Like 61 AP-73.*

The rock is composed of a mosaic contexture with variable grain of calcite including cordierite granules both scattered and gathered in aggregates in form of spots. More seldom cordierite appears in prismatic elongated crystals with multiple twins on (110). They are colourless crystals with low index of refraction, containing abundant carbonious inclusions and zircon, apatite, and probably staurolite monoliths. It is not a highly ferriferous term. In the rock there also a few laminae of flogopite increased with cordierite. With irregular distribution also scattered scapolite granules appear.

61 AP-76. - Crystalline limestone with scapolite. *Like 61 AP-73.*

It is a calcitic granoblastic contexture with very heterogeneous grain with plenty of scapolite scattered in small granules and crystals of macroscopic dimensions with transversal sections of octahedrical form and longitudinal bipyramidal sections. The porphyroblasts are closely grown with calcite and have abundant carbonious material as host.

61 AP-77. - Crystalline limestone with celsiane, cordierite, dolomite, and flogopite. *Like 61 AP-73.*

In a contexture of spathic calcite crystals, big and very limpid there are unhomogeneous spots of contact minerals also isolatedly placed.

The bigger spots appear in the outcrop as yellow-greenish coloured sticks made up of a very thick aggregate of celsiana crystals bordered by a sericitic felt, more seldom mingled to garnet granules. Other zones appear

turbid for limonitic pigments in a calcareous microgranular matrix including celsiane crystals as hosts, together with other crystals of cordierite and dolomite. Outside these zones the above mentioned crystals develop as isolated porphyroblasts with very evident crystalline form: celsiane in rhombic sections with imperfect polysynthetic twinning, cordierite in hexagonal or bipyramidal sections, dolomite in perfect rhombohedra with ferriferous oriented inclusions. The are also some beautiful basal laminae of flogopite mica.

61 AP-137. - Saccharoid marble slightly scistose and micaceous. *Kotal-i-Kaferan.*

Microcrystalline calcite including spathic equigranular crystals, slightly oriented and with paracrystalline deformations. Some granule of quartz and muscovite laminae are also present.

61 AP-138. - Schistose micaceous marble. *Below Kotal-i-Kaferan, toward east.*

On a contexture of analogous composition to sample 61 AP-137 is overlaid a more marked schistosity. There is an interposition of calcic microgranular micaceous beds with coarse granoblastic beds.

61 AP-140. - Massive micaceous saccharoid marble. *Like 61 AP-138.*

Aggregate of calcitic anhedral patches sutured to indented borders including a thick granulation of ematite and tabular laminae of muscovite placed with no orientation.

61 AP-141. - Crystalline limestone. *Like 61 AP-138.*

It is a calcitic aggregate of variable granulometry, with porphyroblasts with rather confused borders and intergranular claye yfilm. There are ematite granules in good quantity.

61 AP-144. - Crystalline dolomitic limestone with flogopite. *Gorge SW of Wurmal.*

Microcrystalline homogeneous aggregate of calcite and dolomite in equivalent quantity, intensely pigmented by ochraceous products. In this con-

texture pleochroic yellow laminae of flogopite and roundish ematite nodules are often scattered. There are also nests of granoblastic quartz and, more seldon, quartzius granules with detritic form.

61 AP-145. - Zoned detrital crystalline limestone. *Pa-in-Shahr valley: 1300 m a.s.l.*

The rock presents an aggregate of calcitic xenoblasts in prismatic form highly iso-oriented. The same orientation is followed by the microgranular beds, slightly turbid, that give to the rock a marked zoned texture. In its oriented growth calcite includes many clastic granules of quartz and potash feldspar deprived of metamorphic effects.

61 AP-146. - Dolomitic crystalline arenaceous limestone with flogopite. *Pa-in-Shahr valley: 1700 m a.s.l.*

The rock presents a very irregular distribution of metamorphic and detritic elements in a calcareous dolomitic semi-crystalline contexture with diffused limonitic pigmentations. The clastic elements are quartz, potash-feldspar and acid plagioclase.

A good recrystallization occurs in oriented zones recognizable as limpid granoblastic beds of calcite. There is also formation of flogopite in beautiful basal laminae also of great dimensions.

61 AP-147. - Metamorphic microconglomerate. *Pa-in-Shahr valley.*

A calcareous matrix, that is arenaceous and metamorphic, includes marble and quartzitic pebbles. Matrix presents a very complex composition in which essentially mingle variously recrystallized calcite-quartz-feldspath detrital granules, marble fragments, dolomite, sedimentary and metamorphic quartzite fragments. Locally, mainly at the contact with the clastic micaceous schistose beds, muscovite and chlorite are formed. Neoformations of flogopite occurs, on the contrary, with reduced and imperfect laminae in open order.

Among the pebbles saccharoid fine-grained marble and granoblastic quartzite are recognizable.

61 AP-148. - Coarse metamorphic sandstone. *Pa-in-Shahr valley, 1700 m a.s.l.*

The rock has the composition of the cement described in sample 61 AP-147.

61 AP-150. - Microcrystalline limestone. *First tributary river, on the left hand side, of the Darya-i-Kalawch.*

It is a calcitic very homogeneous microcrystalline aggregate with nests of autigene quartz and scattered granules of iron oxides.

61 AP-151. - Detritic microcrystalline limestone. *Below the peak 3151 m a.s.l. on the left hand side of the Kalawch valley.*

Calcareous microcrystalline contexture with plently of quartz fragments of various dimensions and some small quartzite fragments. There are also dolomite rhombohedra. Marked limonitic pigmentation with irregular concentrations.

61 AP-152. - Brecciated microcrystalline limestone. *Outlet of the Kalawach valley.*

In a calcareous microcrystalline matrix much impregnated by limonitic arenaceous material there are roundish pebbles and angular fragments of different nature.

In the matrix there are partial recrystallizations of calcite and dolomitic rhombohedra of substitution. The smaller clastics, very abundant, are given by quartz and by some feldspars; the bigger ones consist of more or less sericitic quartzites sometimes feldspathic.

61 AP-153. - Detrital microcrystalline limestone. *Like 61 AP-152.*

Microcrystalline calcitic aggregate with irregular zones with coarser granoblastic structure and quartzous clastics abundantly scattered.

61 AP-154. - Detrital microcrystalline limestone, nodules of flint. *Like 61 AP-152.*

In an rock analogous to sample 61 AP-153 there are lenticular nodules

of flint formed by a fine chalcedonious aggregate. Both limestone and flint appear filled with scattered dolomitic rhombohedra of neoformation.

61 AP-155. - Crystalline dolomite. *Darya-i-Shiwa.*

It is an aggregate of dolomite rhombehedra of big size with small interstitial calcitic patches with indented suturations.

61 AP-156. - Zoned crystalline limestone. *Like 61 AP-155.*

The rock is composed of thickly interposed beds of microgranular calcite and spathic calcite with elongated and markedly oriented crystals. The detrital components are given by quartz granules partially recrystallized, diffused without orientation as to the lamination, and by roundish ematite granules.

61 AD-2. - Biotite-garnet quartzite. *In the left-hand side of outlet of the Warduj valley in the Baharak basin.*

The rock has a granoblastic texture, passing to lepidoblastic. It is microgranular, with a fairly straight schistose texture, emphasised by small flakes of biotite, which although do not gather in clusters, are iso-oriented. The quartz has a straight extinction, and the garnet crystals are rare. However, they are large, and have a late crystallization.

61 AD-2/2. - Biotite-garnet hornfels. *Same locality as 61 AD-2.*

A rock with a granoblastic microgranular texture, with a heteroblastic character due to the late fracturing of the large garnet crystals, which cut across the schistose texture. The grains appear fractured, with local crystallization of chlorite within the fractures. This texture is produced by the previous minerals, and especially by small flakes of biotite. The plagioclase has an An content of 50-70%.

61 AD-12. - Biotite-garnet hornfels. *Near the Ali Mughul bridge (Jurm).*

A rock with a matrix composed of microlites of quartz and graphite, and subordinate feldspathic microlites which are about 0,05 mm in size. They are disposed in a schistose linear texture. In this framework, which recalls that of a graphitic phyllite, there are flakes of biotite which merge

with the matrix at the margins; they are locally replaced by chlorite, and subidiomorphic crystals of garnet ranging up to 1 mm in size.

61 AD-25/2. - Quartzitic sandstone. *In the valley below the pass 1490 m high on the way to Darra-i-Wakhsi (NE of Kishem).*

An immature sandstone, with a matrix representing about 20% of the rock. It is fine-grained, and mainly composed of quartz grains and subordinate feldspars. The grains have a high degree of roundness, but are not well sorted (maximum dimensions range between 0.3 and 0.4 mm). The matrix includes the same mineralogical elements that form the coarser clastic particles, with the addition of micas and opaque minerals. This sandstone must have originated from the decomposition of a crystalline acid rock.

61 AD-28. - Phyllite. *To the north of the pass 1494 m high, NE of Kishem. Not in situ.*

A rock with a fine granoblastic texture, in part lepidoblastic as a result of bands in which small micaceous flakes are predominant. There is a schistose texture in bands with more than one arrangement of planes of scistosity, which suggest that there is an overlapping of several phases of deformation. The deformation which determined the banded schistose texture, represented by the alternation of quartz-feldspar and micaceous bands, was followed by a second deformation. This second deformation determined another arrangement of planes oblique to the first, and (in a contemporaneous or subsequent episode) relative movement of the various bands of original schistosity with strain slip cleavage in the most rigid quartz-feldspar bands. These were in turn filled by crystalline quartz in aggregates of greater dimensions than those of the groundmass (0.2 mm as apposed to 0.5 mm).

61 AD-31. - Quartzitic sandstone. *Near Kangurchi (Kishem).*

A fine grained immature sandstone with a matrix greater than 30%. The clastics comprise grains of quartz, with maximum dimensions of 0.5 mm, probably supplied by crystalline acid rock or by schists with a high degree of metamorphism, and subordinately by alkaline feldspars. There is a low degree of sphericity, and the edges are well rounded(but the degree

of sorting is poor; the individual clastic grains are separated by abundant matrix material, in which white micas, tourmaline and opaque minerals occur, apart from the minerals which form the clastics.

61 AD-42. - Feldspathic quartzite near the contact with the granodiorite 61 AD-41. *Upper Bula-i-Ailah valley. Above Zandalu Darrah-i-Balu (Kalafghan).*

A rock with a mosaic texture, with aggregates distributed in size of about 0.5 mm; sometimes other aggregates have been welded together, by late recrystallization, forming irregular shaped clusters 4-5 mm in size. The feldspar, representing about 15% of the rock, is crystallized in aggregates of smaller dimensions, and is interstitial. It always shows inclusions of white mica, formed along the cleavage planes (sericitization).

61 AD-43. - Sandy siltite: most common type of local rock. *Below the saddle to WSW of Qara Tut (Kalafghan).*

A detrital rock with a pseudo-augenized and laminated texture (in the sedimentary sense). About 50% is angular clastic quartz, ranging in size between 0.1 and 0.05 mm, together with subordinate opaque minerals. The remainder is composed of matrix, which consists mainly of small white mica flakes, which surround the individual detrital grains, thus producing the pseudo-augenized texture, and emphasising the lamination.

61 AD-44. - Quartzitic sandstone. *Near Qara Tut (Kalafghan).*

Poorly sorted immature sandstone, with a matrix greater than 30%, and with unsorted monomineralogical clastics mainly made up of quartz. The clastics vary in size from a maximum of 2 mm, to a minimum of 0.05 mm, with a high degree of roundness but less sphericity. A few of the larger clastics are polycrystalline, being formend of welded grains of quartz.

61 AD-45. - Argillite. *Below point 3123 m in the upper Qara Tut valley (Kalafghan).*

A pelitic rock with a laminated texture (in the sedimentary sense), produced by amygdaloid detritals of medium dimensions around 0.02 mm. They are separated by iso-orientated micaceous flakes. A banded schistose tex-

ture, transverse to the first and due to the alternation of beds which are more or less rich in micaceous flakes, is superimposed.

61 AE-48. - Epimetamorphic sandstone. *NW of Darrah-i-Jim.*

Granolepidoblastic rock with a schistose, pseudo-augenized texture, and a detrital appearance. The pseudo-augens are produced by grains of quartz and feldspar ≅ 0.5 mm long, which are undoubtedly of a clastic origin; these, not completely remobilized, form little augens in a matrix of smaller grains. The remaining quartz and remobilized feldspar are recrystallized in aggregates consisting of smaller grains and having a mosaic texture. The small micaceous flakes are very well iso-orientated and accentuate the schistosity.

61 AE-49/1. - Fine-grained feldspar sandstone. *Pasha Darrah.*

Fine-grained, submature sandstone with very well sorted clastics, and ranging between 0.1-0.2 mm; the clastics are generally separated by small micaceous flakes which surround them; they have a slightly elongated shape and lobate margins; occasionally a few of them are welded with lobate and sutured contacts, which indicate a partial mobilization of silica. Also present are veins of fractured quartz with a mosaic texture, the grains of which range in size between 0.3-0.4 mm.

61 AE-75. - Fine-grained quartz sandstone. *Ridge to the west of altimetric point 2053 m (south of Astana Tepa).*

Fine-grained immature sandstone. The clastics are not well sorted and vary in size from a maximum of ≅ 0.6 mm down to matrix sized particles. The matrix is more than 30% of the rock. The clastics are represented mainly by quartz fragments of various sizes, with round margins, the plagioclase is subordinate. Small flakes of white micas and sub-iso-orientated chlorites are also present in the matrix.

61 AE-82/1. - Quartzitic microconglomerate. *Altimetric point 1291 m east of Farkhar.*

Detrital rock composed of ellipsoidal clastics, with the largest axis a few millimetres in lenght and eroded edges; petrographically, these fragments

are derived from quartzitic rocks of variable grain size; the quartz microblasts are in various stages of recrystallization, and in the most advanced state they appear to consist of a single quartz crystal, in which its origin from the fusion of smaller crystals can still be osserved because of their irregular extinction. The margins of the individual clastics, analogous to those of the sandstone which form part of the matrix, are emphasized by oxides of iron and opaque minerals, which form the remaining part of the matrix.

61 AE-82/2. - Mica rich phyllite. *Like 61 AE-82/1.*

Microgranular rock of a granolepidoblastic, schistose texture; the quartz forms blasts of an irregular elongate shape, which, with those of feldspar, are sometimes separated by thin flakes of white micas and biotite. These micas, although never found together in bands, shows an excellent iso-orientation; small granules of opaque minerals and small plates of iron oxides, in transverse veins, are very common. Section 61 AE-82/4 differs from this by a smaller content of white and dark micas, and by the lack of schistosity.

61 AE-82/3, 62 AE-82/5. - Microgranular feldspathic sandstone. *Like 61 AE-82/1.*

Fine-grained immature sandstone, from the mineralogical and textural point of view. The clastics are represented by unequal fragments of quartz and feldspar. Feldspar forms about 20% of the rock. The matrix is more than 30%, and consists, besides quartz feldspar, white micas, biotite and zircon of minute flakes of micas and granules of opaque minerals.

3. PLUTONIC ROCKS

3.1. Jalmish Tonalite

61 AD-26. - Tonalite. *Above the pass 1490 m, SW of Kishem Probably not in situ.*

A rock with a hypidiomorphic granular texture composed of medium to large grains. The leucocratic constituents are quartz, whith an undulatory

extinction, and zoned plagioclase, whith a maximum An content of 40%. K-feldspar is rare, and there are few myrmekitic aggregates. The melanocratic components are represented mainly by biotite and hornblende in almost equal quantities. The epidote is pistacite.

61 AD-27. - Diorite. *To the west of the pass 1490 m, SW of Kishem. Probably not in situ.*

A rock with a hypidiomorphic granular texture composed of medium to small grains, in which the leucocratic and melanocratic components are equally rapresented. Among the leucocratics, plagioclase, which is often zoned, is the most abundant, and has an An content up to 60% (labradorite). Often, in the central part, the plagioclase includes epidote, which originates from the disintegration of the anorthite molecule. Quartz is subordinate, with crenulate margins. Among the melanocratics, green hornblende predominates over biotite.

61 AD-32. - Quartz diorite. *Near Darrah-i-Shah-Baba bridge.*

The rock presents a coarse unhomogeneous grain mostly for the irregular distribution of the components.

Plagioclase, with euhedral prismatic form, is composed of andesine 44-45% An, with normal zoning passing to albite-oligoclase in the perypheral parts and with very developed geminations. It gathers in groups of crystals thickly interpenetrating and associated to biotite, as quartz is isolated in limpid very anhedral patches, of centimetre dimensions.

Biotite also presents great changes, from small lamellar aggregates corroded and partially chloritized of great tabular euhedral and fresh patches. Chloritization forms radiated nests inserted in the intergranular gaps among plagioclases.

Very seldom there are orthose relics quite totally readsorbed among the quartz crystals.

61 AD-33. - Quartz-leucodiorite. *Above Sang Ab (Kishem).*

A rock with a granular allotriomorphic texture, passing to granoblastic. The highly remobilized quartz is recrystallized in aggregates composed of a mosaic of small crystalas with serrated margins, the extinc-

tion is straight or slightly undulatory. The zoned sodium-calcium plagioclase occurs as allotriomorphic crystals of large size (up to 3 mm); they have undergone an energic process of saussuritization with the liberation of epidote, prehnite and albite.

61 AD-33/1. - Amphibole diorite. *Near Kangurchi* (*Kishem*).

A rock with hypidiomorphic granular texture with medium-sized grains, in which femic minerals are predominant over those of the leucocratic group. Green hornblende is most abundant, followed by chlorite. Epidotes and white micas originate from the saussuritization of the plagioclases, and these are often zoned, with a labradiorite composition (60% An decreasing towards the periphery). Quartz is rare, with a strong undulatory extinction. A fracture is also present, filled with prehnite.

61 AD-39. - Quartz diorite with biotite and hornblende. *Above Darrah village.*

It is a rock medium-grained, very rich in plagioclase and mafic components, with subordinate quantity of quartz and with scarce crystals of orthose quite totally readsorbed.

Plagioclases appear with marked euhedral crystals in rectangular sections and pseudoexagonal, with well developed twins and marked zoning, from a very altered core of labradorite, to a more limpid and generally not geminated oligoclasic periphery.

Among the mafic components a red-brown very pleochroic biotite generally prevails in lamellar chaotic groups full of segregations and interpenetrating with hornblende specimens from which they came.

Besides these groups there are also some isolated biotitic euhedral patches, also of great dimensions.

Hornblende shows some prismatic pleochroic yellow-green and blue-green coloured sections, sometimes geminated, always containing biotite of neoformation in lamellar nests inside the crystals or as borders and spots.

61 AD-41. - Granodiorite. *Upper Bula-i-Ailah valley. Above Zandalu Darrah-i-Balu* (*Kalafghan*).

It is a fine-grained rock in which some euhedral plagioclase prisms come

into evidence followed by potash-feldspar and quartz in crystallization order.

Plagioclase shows marked zonings with a core of basic andesine 46-47% An, and border of pure albite. Orthose forms anhedral specimens also of great dimensions covered by kaolinic orthose of neoformation. It is corroded an descavated deply by quartz that crystallizes in quite granoblastic groups of very limpid specimens, seldom with undulating extinction. Biotite is also much corroded and reduced in lobated or poikilitic rags, full of segregations of iron oxides sometimes chloritized.

61 AE-43. - Quartz diorite. *Near Kwaja Afghani.*

The rock has granular very marked structure dominated by an interlacing of euhedral prisms of not very quartzous plagioclase and much biotite. The prisms of plagioclase labradorite 52-55% An albite, albite-Carlsbad, penetrating in musaic forms.

The gaps among the plagioclase crystals are filled by quartzous patches with marked undulating extinction that sometimes are in concretions in form of spots and drops in the feldspar. Along the margins of the feldspathic prisms quartz sometimes takes a microcrystalline form as in plagioclase reaction borders of albitic composition appear. Red-brown intensely pleochroic biotite appears in patches of laminae with centimetre dimensions including many prisms of apatite, granules of zircon, titanite and with diffused marginal segregations of magnetite.

The micaceous patches are intensely corroded by the sialic minerals and deformed in undulations and folds without fractures.

61 AE-46. - Amphibole gabbrodiorite. *South of Darrah-i-Jim.*

A hypidiomorphic granular rock in which the leucocratic minerals are predominant over the coloured ones; the plagioclase is the most common constituent, and it forms about 70% of the rock, with crystals up to a maximum of just over 4 mm along the direction of the c axis; it has a variable composition, ranging between 60% An (labradorite) and 80% An (bytownite); the crystals are often zoned, and their central part is often altered into saussuritic mesh. Quartz is rare and interstitial. The femic minerals are green-brown hornblende and biotite; the latter is for the most part either in

a reabsorption stage, or has been changed into a thin cover of small chloritic flakes.

61 AE-47. - Leucodiorite. *SW of Darrah-i-Jim.*

A hypidiomorphic granular rock with grains up to a maximum of 3 mm. About 80% of the rock is plagioclase of an andesine-labradorite type, which is often zoned and always largely saussuritized. Quartz is scarce, < 10%. The chlorite crystallized later in the penninite variety, and random clusters; the calcite is reabsorbed.

61 AE-57. - Granodiorite. *Near Sang Ab.*

The rock has a sialic very granular contexture with lamellar biotitic groups and amphibolic prisms.

In the sialic part it is recognizable a plagioclase andesine 38% An slightly pericline with marked normal zoning, in euhedral prisms with rectangular or hexagonal section in many twins. Their core is often alterated in kaolinic material with sericite neoformation.

Anhedral specimens of ortose of small dimensions appear associated to plagioclases in quantity subordinate to them. Also quartz in interstitial patches of different dimensions, with indented borders with undulating fractures and extinction appears. Biotite and hornblende are tightly increased in scattered groups without order often in rags, fibres or poikilitic patches.

Hornblende presents an increased pleochroism: N_p = grass-green, N_m = yellow-green, N_g = blue-green.

Biotite is sometimes chloritized.

61 AE-58. - Quartz diorite. *Near Sang Ab.*

The rock has a marked anhedral structure and an essentially plagioclasic amphibolic composition.

The sialic contexture is mostly composed of an interlacing of andesine An 40-42% prisms much zoned and often innerly increased, with marked saussuritic alterations and neoformation of calcite, sericite, zoisite, and quartz plunged in an argillaceous isotrophic substance. Sometimes these products grow alone, mainly zoisite that comes into evidence in beautiful colum-shaped

prisms and calcite that gives birth to rhombohedral limpid patches. Not very abundant quartz is always in interstitial form. Among the mafic components beautiful hornblende prisms with rhombic and pseudo-hexagonal sections prevail. They have distinct pleochroism: N_p = yellow-brown, N_m = reddish-brown, N_g = red-brown. They appear intersected and often disarranged by thick microfractures along which an intense transformation at first into biotite, than into chlorite appears.

Chloritization is very advanced so that also biotite appears in form of relics. Primary biotitic laminae are scattered in moderate quantity. They are chloritized, too.

61 AE-72. - Microdiorite. *Near Khand Asman.*

The rock is characterized by a groundmass very developed, with ophitic-interstitial structure, made up of a plagioclase, hornblende, and a little quartz containing plagioclase phenocrystals with perfect prismatic form.

Plagioclases of the groundmass present elongated prism strongly interlacing and filled by sub-idiomorph hornblende granules; phenocrystals have the form of squat prisms often with pseudo-hexagonal borders. Both forms have the composition of labradorite 55-57% An, and are zoned, twinned and transformed in sericitic felts and argillaceous products.

Among the mafic components, besides green hornblende, there are small altered and chloritized biotite laminae.

61 AE-76. - Tonalite. *To the south of altimetric point 1972 m (SE of Astana Tepa).*

A hypidiomorphic granular rock with crystals of different sizes. Along the c axis, plagioclase reaches 5 mm, of an andesinic-labradorite composition, often zoned and often saussuritized. Quartz shows itself in crystals of dimensions which are variable within wide limits, but in most cases the crystals are smaller than those of plagioclase. The quartz is crystallized in plates in the interstices left by the plagioclase, or in strips of greater continuity; the contacts between the granules are lobed and sutured. Biotite is common, but the geometry of the flakes shows that they have been partially reabsorbed by the leucocratic minerals; green hornblende, joined to biotite, is subordinate.

61 AE-83. - Granodiorite. *Near Kashan.*

Very sialic medium-grained rock prevailingly made up of plagioclase, orthose and quartz, with biotite in subordinate quantity.

Plagioclase presents zoned euhedral sections with core of ladradorite 52% An, well geminated, and albite, more limpid and not geminated perypheryphery.

Potash-feldspar, among which much microcline, appears in order of crystallization later than plagioclase that it surrounds and markedly corrodes. Among the big quartz patches, feldspars are often included in form of partially readsorbed relics in which plagioclase has a central position and potash-feldspar a marginal one, quite a border.

61 AE-84. - Amphibole gabbro-diorite. *Near Kashan.*

An hypidiomorphic granular rock with a slight predominance of leucocratic over femic minerals; the former consist mainly of zoned plagioclase, crystallized in prisms of millimetric dimensions and of a labradorite composition, which are only rarely attacked by the process of saussuritization. Quartz is subordinate, poikiloblastic, with a clear or almost clear extinction, showing contacts engulfed in the other minerals, especially in the femics. The femics are made up of greenish-brown hornblende and biotite, the former being predominant over the latter; both show lobate margins within which are enclosed the leucocratics and the cuspidate ends are in course of reabsorption.

3.2. Muzung Gabbro

61 AP-115. - Gabbro. *300 m downstream from Muzung.*

Rock with medium-coarse-grained ipidiomorph structure, quite exclusively made up of plagioclase and pyroxene.

Big tabular rather wide and squat prisms of diallage with brown-greenish colour are mingled to sub-idiomorph crystals of labrodoritic plagioclase 57-58 An. At the contact with feldspar diallage presents a continuous border of fine green actinolite needles perpendicular to it. Often this acti-

nolitic rim goes on in contact zones between two feldspathic crystals, as if one of them would have substituted a primitive pyroxenic crystals. In this case at the actinolitic border a roundish or lobated form of magnetitic separation is joined. Such segregations often appear also inside the diallage crystals, mainly in the ones interested by interlamellar amphibolic clearings. The rock presents a marked clastesis of all its components with deposit of limonitic substances along the fractures.

61 AP-117. - Olivine gabbro. *Like 61 AP-115.*

Massive fine-grained rock composed of basic plagioclase, pyroxene and olivine.

As in sample 61 AP-115 the femic components generally have wide version borders with plagioclases, joined with noticeable magnetitic segregations. Olivine appears in sections with roundish form surrounded by a micro-fibrous white-greenish border of actinolite, that is sometimes zoned and with interposed thin stripes of crysotile. The fractures are full of red-orange coloured limonitic materials. Pyroxene is represented by rather fresh augite prisms, sometimes twins on (100), light rose-brown coloured, not pleochroic. At the contact with feldspars they are very corroded. In many cases they present roundish or lobated magnetite segregations. Magnetite sometimes completely substitutes them leaving a thin and continuous border of brown-reddish colour, pleochroic, caused by biotite alteration at the margin. Feldspars consist of labradorite sub-idiomorph prisms, lacking in zoning and not much altered, with always present geminations.

61 AP-118. - Amphibolic saussuritic gabbro. *Spur to the north of Ert.*

The rock is mostly formed by a thick saussuritic felt from which some amphibolic crystals, that is altered too, comes into evidence. Saussurite presents different albitic patches, zoisite granules and sericite felts. There are no definite limits for the borders of the feldspathic crystals existing before, to which the saussuritic aggregate confusely mingles with microlamellar patches and needle-shaped bundles of light green amphibole corresponding to an actinolitic term. Antigoritic aggregates in form of roundish or tabular spots substitute former mafic crystals, probably pyroxenic. Antigorite laminae are also recognizable scattered in the amphibolic aggregate.

Prismatic sections of green hornblende come into evidence as porphyroblasts in the described matrix, they are partially substituted by small actinolite prisms and by fibrous radiated aggregates of antigorite; the last ones mainly at the borders.

Everywhere titanite granules are scattered associated in S-shaped rows and irregular groups.

61 AP-119. - Rock with amphibole, pyroxene, calcite and titanite. *Like 61 AP-118.*

The rock appears with a thick and very developed interlacing of tabular acicular and fibrous prisms of hornblende, with a slight pleochroism from colourless, to yellow-brown, to light green. In the thinning points of this felt, euhedral nests of calcite, crystals of titanite, and big euhedral relics of pyroxene completely transformed into aggregates of antigoritic lamellae and partially chloritized appear. Calcite forms large veins and lenses with granoblastic structure too.

61 AP-122. - Amphibolic gabbro. *Head of Sela-i-Kalan valley.*

The rock has granular medium-coarse, ipidiomorph, slightly oriented structure.

The sialic portion consists of well flaked twin anortite 90% An crystals forming an homogeneous aggregates. Green hornblende and biotite appear of earlier crystallization. Hornblende is in long prisms intensely and irregularly corroded. Later fibrous-radiated nests of chlorite are formed in the feldspathic mass. The ferriferous granulations are abundant.

3.3. Naghz Darrah Tonalite.

61 AP-56. - Quartz diorite with garnet and epidote. *Southern side of the Zyarat-i-Kwaja pass.*

The roch presents a granular anhedral structure with preminence of the sialic components.

The presence of many garnet iron crystals and much epidote is noticea-

ble. The sialic parts have plagioclase andesine 40-44% An crystals, of variable dimension, thickly interpenetrating rather calcic and with frequent normal zoning. Quartz appears in anhedral patches that are intensely fractured and with undulating extinction. Biotite shows large, very fresh and pleochroic straw-yellow, green-brown, and red-brown coloured laminae. They often develop from big intensely fractured and dismembered garnets. Also some hornblende crystals appear partially substituted by biotite. Epidote is scattered in cataclastic crystals, generally near zones of biotite with amphibole. An abundant additional element is titanite.

61 AP-58. - Quartz microdiorite with garnet and epidote. *Southern side of Zyarat-i-Kwaja pass.*

The rock has anhedral granular homogeneous and fine, quite granoblastic, structure, with tabular laminae of biotite regularly scattered and small epidote granules and, sometimes, also garnet. In the sialic part quartz appears in roundish granules corroded by feldspar and afterwards undergone to intense recrystallization. Plagioclase, prevailing in quartz, is made up of andesine 43-45% An in fine granules of polyhedric formation, often zoned, with many mechanical post-crystalline deformations. Quartz appears often in them poikilitically included. The inner portions are more basic, and often have incipient saussuritization.

61 AP-59. - Garnetiferous pegmatite. *Southern side of Zyarat-i-Kwaja pass.*

The rock is characterized by poikilitic anhedral structure, that is rather marked and unhomogeneous.

It is possible to distinguish microgranular portions essentially made up of oligoclase-andesine plagioclase in polygonal patches riddled by quartzous drops (graphic structure) and zones in which this microgranular contexture is mingled with crystals of quartz, plagioclase, and microcline; these crystals have big dimensions and are chaotically placed. Of them, plagioclases seem to be grown with quartz in graphic forms and more or less full of antipertitic concretions with microcline. Garnets appear in granules of small dimensions, that are fresh and euhedral. Micas appear mainly in the

microgranular zones with small tabular laminae of biotite and a few gathered laminae of muscovite grown with feldspathic crystals.

There are scarce epidote granules.

61 AP-61. - Garnetiferous pegmatite. *Southern side of Zyarat-i-Kwaja pass.*

The rock differs from sample 61 AP-59 on a greater diffusion of microcline and a more marked grain, though zones with fine anhedral structure remain. On these zones potash-feldspar appears of contemporaneous composition of plagioclase as in the zones with pegmatitic structure. Potash-feldspar is of later genesis with strong reabsorptions and formation of albitic rim in plagioclase. This one has a medium oligoclasic composition 15-20% An. Rather frequent are garnets and scarce micas among which muscovite prevails.

61 AP-62. - Quartziferous diorite with quartz and epidote. *Southern side of Zyarat-i-Kwaja pass.*

It is a rock similar to sample 61 AP-56.

The only differences is given by their content of micas, that here have development of muscovite and biotite. Marked zoisite crystals are developed in the core of plagioclasic zoned specimens going to be saussuritized, too.

61 AP-65. - Quartzous-plagioclasic pegmatite. *Southern side of Zyarat-i-Kwaja pass.*

The rock is quite completely formed by quartz in big specimens regularly laid and of albite-oligoclase 9% An in crystals of centimetre dimensions. They are specimens partially limited by cleavage drops, characterized by antipertitic concretions with microcline. In them there are many para or post-crystalline deformations with opening of micro-fractures filled by microcline and granoblastic quartz coming from the patches surrounding it. Micas are absent.

61 AP-66. - Quartzous-plagioclasic pegmatite. *Southern side of Zyarat-i-Kwaja pass.*

The rock is only made up of big quartzous crystals intensely fractured and with undulating extinction sorrounding and corroding the smallest specimens of albite oligoclase, that are partially euhedral and sometimes slightly zoned. Some intergranular gaps are full of tabular very fresh muscovite patches or of epidote granules much deformed. The late introduction of potash-feldspar, noticed in sample 61 AP-65, is absent.

61 AP-109. - Dioritic gneiss. *In the valley between Dew Darrah and Bazgeran villages.*

The rock looks like a diorite with very oriented texture, with irregular distribution of the sialic elements.

They are mostly given by plagioclase labradorite 56-58% An in zoned crystals, partially saussuritized, some in form of euhedral iron crystals, others gathered in quite granoblastic groups. Quartz, in smaller quantity, appears as scattered interstitial or included granules in the amphiboles or plagioclases. The femic components, equal to the light ones, are represented by abundant euhedral prisms of green hornblende placed without orientation, isolated or in wide groups. From their transformation many biotitic laminae come and grow in orientated way, undergoing to an incipient chloritization.

61 AP-111. - Granodiorite with biotite. *Near Langar.*

The rock presents granular euhedral rather coarse structure. The composition is rather sialic, prevailingly quartzous-plagioclasic, with scarce microcline. Biotite is frequent, epidote is a diffused additional element. In the sialic parts there are big quartzous sutured patches and oligoclase crystals with irregular spots because of the variations of composition and many imperfect twins, with advanced saussuritic transformations. Microcline appears in very anhedral patches among the quartzous-plagioclasic specimens at the contact with which it develops marked micropegmatitic and myrmekitic concretions. Biotite forms wide tabular laminae, with peripheral transformations, with muscovite and feldspathic inclusions enclosed during their growth.

61 AP-120. - Quartziferous diorite with biotite and hornblende. *In the valley between Sahid Darrah and Kalan villages.*

Rock with ipidiomorphic granular structure with prevailing feldspar, made up of plagioclase, anhedral quartz, much biotite, hornblende and products of saussurritic alteration of plagioclases.

Plagioclase is formed by euhedral prisms of andesine 45-46% An of variable dimensions, sometimes in fenocrystals with complex markedly developed twins and marked normal zonings. The saussurritic products are prevailingly given by sericite and epidote. Epidote increases in beautiful prismatic pseudomorph crystals on the plagioclases. Plagioclases are sometimes substituted by biotite in patches of big fresh laminae, very pleochroic, bent or broken under dynamic paracrystalline actions, including quartz granules poikilitically. These deformations seem to be contemporaneous to the first form of recrystallization of quartz in sutured patches often deformed in lenses and strips with marked undulating extinction. Afterwards, a part of quartz was recrystallized in granoblastic nests and beds; the beds were placed along old fracture surfaces. Hornblende appears in prisms poikilitically grown with plagioclase, and later much corroded and partially transformed into biotite. Titanite and apatite granules appear in secondary quantity.

61 AP-121. - Quartz diorite. *On the pass between Kalan and Sela-i-Kuhrd villages.*

It is a rock different from sample 61 AP-120 only on a diffused cataclastic structure and a great abundance in epidote.

61 AP-131. - Adamellite. *In the valley near Palang Darrah.*

It is a very acid rock with granular not very homogeneous anhedral structure, essentially made up of a confused mixture of microcline, oligoclase, plagioclase and quartz. All the feldspars show diffused alterations and neoformation of sericitic felts and muscovite laminae. Biotite is rather unstable, bordered by light mica and often amassed in turbid and de-fibred lenses. A diffused recrystallization of quartz is contemporaneous to these deformations.

3.4. Baharak Granodiorite.

61 AP-67. - Granodiorite (Trondhjemite). *Above Malang Ab.*

It is a distinctly granular rock composed of euhedral zoned fenocrystals of plagioclase, quartz and biotite.

Plagioclase is an andesine term 31-38% An with abundant normal zoning. The geminations are frequent and well developed, specially as Carlsbad, Albite-Carlsbad, Albite-Pericline, and Baveno. Their margins present fine indented forms for the concretion with a thin quartzous border. The contact is often marked by myrmekitic structure and it is distinguishable also for a micro-flooring structure. In the other zones quartz presents an aggrgate of isodiametric granules of medium dimensions, very limpid, and without mechanical deformations. Biotite laminae are generally wide, furnished with a perfect basal cleavage, with intense pleochroism straw-yellow, and marked brown slightly greenish. They are surrounded by a thin rim of titanite granules that are sometimes poikilitically included in the mica.

61 AP-81. - Leucogranite. *Block of the Ardar landslide.*

Microcline and quartz are the prevailing components, among which biotite laminae and scarce plagioclase are found.

As additional minerals there are many apatite crystals and iron oxides. The structure of the rock is dominated by the idiomorphism of potash-feldspar that tries to form fenocrystals of great dimensions. Frequently ther are micropertitic concretions with plagioclase. Some optical features of microline: $2_V = -81°\text{-}88°$, $N_p\ (001) = 5°$, $N_p\ (010) = 14°$. Quartz is placed in wide anhedral patches with indented and sutured borders, and it often intrudes into the feldspathic crystals.

The rock underwent an intense cataclasis visible in all its components, mainly in quartz. After it there are no signes of recrystallization.

61 AP-83. - Leucogranite. *East of Dashtek.*

It is a very sialic rock with fine grain, characterized by the xenomorphism of all its components.

Plagioclase (andesine 31% An), potash-feldspars (microcline and microclinpertite) and quartz in smaller quantity, interpenetrate in a very thick aggregate, full of concretions and reciprocal clearings and covered by wide zones of kaolinic alteration. Potash-feldspar substitutes plagioclase in some cases; plagioclase assumes an acid rim of albite at the contact. In this aggregate big quartz patches sometimes come into evidence. They have indented borders and marked undulating extinction. Micas are given by little biotite in isolated laminae teared at the border and by scarcer muscovite.

61 AD-4, 61 AD-5. - Granodiorite. N. 4: *Zardew valley, little downstream from Balkai-iMalang Ab.* N. 5: *Zardew valley, near Joibar.*

A rock with a hypidiomorphic granular texture with medium-large grains, having no orientation. The K-feldspar is composed mainly of microcline with grid twinning. The quartz and plagioclase occur generally in a myrmekitic intergrowth, or in grains in juxtaposition, as a result of lobate and crenulated margins. In the plagioclases, the maximum angle of extinction measured in symmetric zones, is 13°, the corresponding An content of which is < 10%. The micas are of a biotitic type in section D4, whilst they are of the white mica variety in section D5.

61 AD-7. - Leucogranite. *Warduj valley, near Ushkan. « White granite ».*

A rock with a hypidiomorphic granular texture with medium-large grains, having no preferential orientation. Quartz is the most abundant component. It is highly fractured, and has an undulatory extinction, and is often in a myrmekitic intergrowth with oligoclase (30% An). It is also found as transparent crystals, without any inclusions. The K-feldspar is more or less kaolinized; micaceous lamellae are rare and, among them, biotite is the most abundant.

61 AD-10. - Quartz diorite. *Blocks of the morainic dam of the outlet of the Zardew valley. « White granite ».*

A rock with a hypidiomorphic granular texture with medium-large grains, without orientation. The plagioclase is often zoned, with an An content up to 30%, and is often altered into prehnite in its most calcitic central part. The allotriomorphic quartz has an extinction ranging from undu-

latory to highly undulatory. Large flakes of biotite are evenly dispersed in the section.

61 AD-9/1. - Quartzdiorite. *Warduj valley: near the Ardar bridge.*

A rock with granoblastic texture and heteroblastic character. Feldspar crystals attain the greatest size. The plagioclase is often zoned, with an An content up to 40% (andesine). The quartz forms crystals of smaller sizes with a clear or slightly undulatory extinction, and often with triple jointing. Chlorite is present as a secondary mineral, by alteration of the biotite.

61 AD-9/2. - Quartz microdiorite. *Warduj valley: near the Ardar bridge.*

A rock with a hypidiomorphic granular texture, with minute grains. Plagioclase is the most abundant leucocratic mineral, containing 30% An (oligoclase-andesine), quartz is associated with a clear or slightly undulatory extinction, the femics are abundant, and among them, hornblende ($c: \gamma = 16°$).

61 AD-13/1 - Granodiorite with two micas. *Same locality as 61 AD-13.*

A rock with a hypidiomorphic granular texture and heteroblastic character, due to the very wide range of sizes of the different constituents. Plagioclase (20% An) and K-feldspar, either twinned in the Carlsbad law, or with the typical grid twinning of microcline, are present. They are generally separated from micaceous and chloritic flakes by aggregates of crystals of remobilized quartz. The crystals are smaller in size, with lobate and crenulated margins, and with an extinction which is sometimes straight, sometimes undulatory. Within the quartzitic plates, there are poikiloblasts of fractured garnet.

61 AD-14. - Leucodiorite. *About 4 km downstream from Tergeran (Warduj).*

A rock with an allotriomorphic granular texture, with heterodimensional crystals. There is no preferential structure, except for a very slight orientation of the biotite aggregates. About 40% of the rock consists of quartz, and undulatory extinction is always present, together with fractu-

res whitin which no other minerals occur. Oligoclase and K-feldspar are never twinned, and they invariably present alteration staining; the biotite occurs as flakes, showing two different kinds of pleochronism:

1° N_g N_m copper-red, brown N_p pale yellowish-brown
2° N_g N_m bright green N_p pale yellowish-brown.

61 AD-16. - Quartzdiorite. *Near Deh Qalat, upstream (Warduj).*

A rock with a hypidiomorphic granular texture with medium and coarse grains. There are zones in which minute grains are present. There is finely banded texture, indicated by a cluster of small, subaligned flakes of biotite. Plagioclase generally is not twinned, and corresponds to a composition of 40-45% An. The quartz shows a constant undulatory extinction, and clear signs of mechanical pressure.

3.5. Abu Abdal Granodiorite.

61 AP-29. - Adamellite. *Near Wular.*

It is a very sialic rock, rich in quartz, plagioclase and ortoclase, with few micaceous minerals.

The grain is medium, the structure granular ipidiomorphic. Plagioclase presents oligoclase prisms 26-29% An, slightly zoned and altered, mainly at the core, in muscovite, the lamellae of which are placed along crystallographic directions of the host mineral. There are sometimes patches of bigger laminae showing clear paracrystalline deformations. At the borders plagioclases are strongly corroded by potash-feldspar, represented by ortose, microcline, and microclinperthite. Potash-feldpar changes its form, from small interstitial nests to big patches including reabsorbed fragments of plagioclase. At the contact myrmekitic forms are often developed. Biotite is rather scarce and grown with feldspathic specimens marking their crystalline margins. Paracrystalline deformations are noticeable also in potash-feldspar and quartz. To them a late cataclasis follows, interesting all the components.

61 AP-49. - Leucogranodiorite. *Near Zyarat-i-Kwaja.*

The rock is on the whole similar to sample 61 AP-104, but a greater diffusion of biotite in small euhedral lamellar patches.

61 AP-104. - Leucodiorite. *East of Sharan.*

The rock has a rather regular ipidiomorph structure and a composition essentially quartz-feldspathic with few micas.

Among the feldspars an acid oligoclase 17-18% An prevails. It is sometimes slightly zoned, in euhedral prismatic sections. It often includes very corroded quartzous granules. Potash feldspar is in anhedral microcline specimens with micropertitic clearings, they too included in quartz. Quartz presents patches of variable granulometry, partially substituting to feldspars in plagioclases. In plagioclases there are alterations in sericite, the lamellae of which are placed in oriented groups sometimes grading to a muscovite. Biotite appears with some laminae of primary origin, partially substituted by chlorite. An intense cataclasis with fractures interests all the components and in quartz also strongly undulating extinction appear.

4. ROCKS OF THE MYLONITE BELTS.

61 AE-21. - Tonalite. *South of Masar Misi, 18É m a.s.l.*

A granular hypidiomorphic rock with a heterodimensional character, due to the different grain sizes of the various mineralogical constituents. The largest crystals are represented by prisms of green hornblende , which attain a lenght of 4-5 mm, and have irregular margins, indicating that they were corroded by highly remobilized quartz. Another mineral present, together with hornblende in very small quantities, is biotite, in curved flakes of 1-2 mm in lenght, showing undulatory extinction and frayed margins. Among the leucocratic minerals, the sodic-calcic plagioclase is the only feldspar, having 0.5-2 mm crystals of andesinic composition; the remobilized quartz is recrystallized, and shows a fine granoblastic texture ($\cong$ 0.1 mm).

61 AE-22. - Biotite-amphibole orthogneiss. *West of Mazar Misi: metamorphic belt.*

Granoblastic texture, (partly lepidoblastic), and schistose-gneissic texture, due to the iso-orientation of the micaceous flakes and of discontinuous streaks of quartz, having a leptinitic texture and undulatory extinction which enclose the amygdaloid sodic-calcic feldspar. The plagioclase contains up to 40% An and is occasionally twinned in the Albite, occasionally in the Carlsbad law, and occasionally not twinned at all. The quartz is also present in microblastic aggregates having irregular margins. The femic minerals are represented by biotite, predominant over the green hornblende, occasionally twinned; accessory minerals are epidote and apatite.

61 AE-22b. - Amphibolite. *Like 61 AE-22.*

Fine-grained rock with granoblastic equigranular texture (0.1-0.2 mm). The green granular hornblende is predominant, prisms are scarce. The plagioclase is subordinate and is rarely twinned.

61 AE-23. - Micaschist. *NW of Petwan.*

A rock of lepidoblastic texture, passing into granoblastic, with a banded schistose texture consisting of alternating bands of predominatly micaceous composition and bands of quartz-feldspathic composition; the banded schistose texture is complicated by microfolds and contortions which are superimposed on the texture by compression stresses which probably occured at a later time; thus, both types of flakes are curved, and occasionally shows accordion folds with undulatory extinction. Almost all the leucocratic crystals are quartz, in equidimensional crystals, although they are of different shapes, and have sutured margins and a strong undulator extinction. The plagioclase is subordinate.

61 AE-24. - Blastomylonitic quartz diorite. *.N Wof Petwan.*

A rock with a granoblastic texture, passing into lepidoblastic, with a not very apparent schistose texture. The most abundant constituent is plagioclase, which forms ≃ 50% of the whole, with individual crystals 1- 2mm long, occasionally with poikiloblastic zoning, due to the inclusion of small crystals of a different kind (epidote, mixture of epidote and pistacite, amphibole

small mica flakes). The quartz is heteroblastic, being present either in aggregates with a mosaic texture consisting of small crystals ≃ 0.5 mm long; or in different-sized blast form, having a strong undulatory extinction and being about 2 mm long, which seems to originate from the fusion of the former; or in streaks with a leptinitic texture. The biotite is present in irregular curved flakes with an irregular extinction. The epidote is well represented also with its varieties pistacite and hortite.

61 AE-25. - Blastomylonitic quartz diorite. *Metamorphic belt west of Kuwaki, 2176 m a.s.l.*

A rock with a granoblastic schistose texture; the most abundant mineral is quartz, either in the form of microblasts of ≃ 0.5 mm forming an irregular mosaic texture, or in blasts of larger and irregular sizes (≃ 1-2 mm), with a strong undulatory extinction, within which the smaller crystals are enclosed. The feldspar is more than 10%, and is represented mainly by plagioclase. Among the micas, the most abundant is biotite, in irregudar flakes with irregular margins.

61 AE-26. - Amphibole diorite. *Pass between Haras Misi and Isak Kiti (south of altimetric point 2176 m of the map).*

A rock with an hypidiomorphic granular texture, medium-grained, in which the leucocratic and melanocratic minerals are equally represented. Among the leucocratics, the feldspars are clearly more abundant than quartz; the former are plagioclases with an An content of 60% (labradorite). Among the melanocratics, the most prevalent is green hornblende, which is generally twinned; the biotite shows highly corroded flakes, and is slowly replaced by plagioclase.

61 AE-34. - Biotite cornubianite. *Some kilometres NE of Qara Kamar.*

A rock with a linear, schistose and fine-grained lepidoblastic texture, produced by fine-grained iso-orientated muscovite flakes, associated with streaks of microgranular quartz. In this aggregate, which can be considered as a matrix, are scattered crystallized nodules of small biotite flakes, intimately associated with very fine granules of opaque minerals; occasionally the micaceous flakes have larger sizes and very irregular margins.

61 AE-36. - Mylonite passing to blastomylonite. *A belt in the granite west of Iskan.*

Clear schistose texture, due to dynamic phenomena; the schistosity is in bands, as a result of the alternation of massive horizons having mylonitic texture and recrystallized bands. There are bands rich in plagioclase crystals, which, although not completely crushed, show signs of intense fracturing. Bands of extremely small flakes of white micas and a few granules of ferriferous epidote reveal the transformation of part of the feldspar. The quartz is for the most part recrystallized in discontinuous streaks, having a mosaic texture and ranging in size from fine to microcrystalline. Finally, small aggregates of calcite with mosaic texture have replaced part of the original leucocratic material, which probably constituted a rock of granitoid type.

61 AE-40. - Amphibolite. *É00 m east of Samati.*

A rock with a non-schistose nematogranoblastic texture. Amphibole and plagioclase are the most common minerals, and represent about 85% of the rock. The amphibole is crystallized in prisms which are slightly pleochroic, representing a member of the hornblende family (angle of extinction $c:\gamma$ $16°$-$24°$), and in fibres belonging to the tremolite-actinolite series. The prisms appear broken up and with eroded margins, due to the progressive replacement by quartz and plagioclase; the latter is poikiloblastic, and includes a large amount of microlites, consisting of fibres of an amphibole, grains of apatite, zircon and zoisite. The quartz forms little streaks with a mosaic texture.

61 AE-42. - Mylonite. *Near Arqa Qeshlaq.*

The rock is characterized by a groundmass of mylonitic nature partly criptocrystalline, partly isotropic, including quartzous and feldspathic specimens together with minerals of saussurritic origin very cataclastic.

Among these inclusions, quartz is the prevailing element diffused in splinters, lenses and roundish masses of variable dimensions. The bigger elements present intense fractures partly zoned by microgranoblastic veins due to following blastesis. All the quartzous elements have marked undulating extinction. There are also some fragments of albite and orthose crys-

tals covered by thin sericitic neoformations. The minerals of saussuritic origin are represented by sericitic fibrous aggregates, by veins and patches of floor calcite, and by granular groups of epidote. Also the ground mass is in great part due to the mylonisis of analogous elements of saussurritic origin.

61 AE-44. - Fine biotitic veined gneiss with cordierite. *Near Kwaja Afghani.*

The rock consists of the alternance of quartzous-feldspathic veins and bands of gneissic composition, with fine-grained biotite and cordierite.

The sialic veins are exclusively made up of limpid quartz with crystalline coarse-grained form, including relics quite totally reabsorbed of biotite and acid plagioclase. The gneissic bands have a fine contexture of quite cornubianitic structure composed of quartz, plagioclase, little potash feldspar, biotite. The cordierite crystals are scattered in the gneissic contexture, but particularly at its contact with the sialic veins. They appear as poikiloblast with polygonal form full of inclusions of biotite, apatite, zircon and spinel; often altered in light mica, talc and isotrope substances with limonitic pigmentation often at the borders.

61 AE-53. - Quartz dioritic blastomylonite. *Near Sang Ab.*

The sample presents a blastomylonitic and quartz-dioritic nature of the original rock.

It is possible to distinguish abundant crystals with euhedral prismatic form of acid oligoclase covered by a diffused patina of argillaceous sericitic alteration that come into evidence as idioblasts on a quartzous aggregate crossed by chloritic veins and rows. In this aggregate a medium granular portion with mosaic look appears. It underwent a moderate recrystallization without clastesis, and a microcrystalline portion in reticular apophysis and bands, made by intense mylonisis and following blastesis, is noticeable too. The original micaceous minerals, probably biotite, were totally chloritized and grouped in veins and rows associated with diffused segregations of iron oxides, sometimes crystallized in cubic forms. Fine tabular biotite laminae without chloritization are seldom noticeable. Muscovite laminae are sometimes found as product of transformation of feldspar, with epidote granules.

61 AE-54. - Blastomylonite. *Sang Ab.*

A rock with a blastomylonitic and slightly schistose pseudoaugen texture because in a matrix of fine-grained crystals are embedded homeoblasts of quartz (0.2-0.3 mm), having a mosaic texture. The microcrystalline part is formed mainly by sodium plagioclase and quartz; local recrystallization has welded part of the microcrystals forming larger ones, in which the suture lines of the original crystals can still be seen. Biotite is scarce, and has been changed into chlorite. The minerals present and their percentage suggest that this blastomylonite derives from a granitoid rock.

61 AE-55. - Microgranular amphibolite. *Sang Ab.*

A fine-grained rock with a diablastic texture, due to interdigitation of the hornblende type amphibole ($c : \gamma$ 18°-25°) and the plagioclase. A few crystals of plagioclase and amphibole are present, the sizes of which are about a millimetre, and give them a clearly porphyroblastic appearance. The rock is permeated by a network of small fractures, filled with chlorite or calcite.

61 AE-59. - Biotite paragneiss. *Small valley SE of Sang Ab.*

A rock with a granoblastic (partly lepidoblastic) banded schistose texture, due to the alternation of zones in which quartz with felspar is predominant and micas are subordinate with others having a gneissic composition. The contacts are quite distinct. The quartz veins consist, for the most part, of transparent heteroblastic quartz (0.2-0.5 mm), having lobate margins and sericitized interstitial feldspar. In the zones with a gneissic composition, the sodium-plagioclase is predominant, and it is generally highly sericitized and accompanied by small iso-orientated flakes of biotite and quartz.

61 AE-61. - Blastomylonite. *Kangurchi valley.*

A rock with a blastomylonitic texture in which microcrystalline zones, produced by strong fracturing, followed by weak recrystallization, alternate at random with medium-grained zones. The latter are due partly to more intense local recrystallization which produced granules of larger size, and mainly to crystals which, although showing strong distortions of their crystalline structure, have generally resisted fracturing.

61 AE-62. - Staurolite gneiss. *East of Kangurchi.*

The rock consists of a fine, regularly oriented aggregate of quartz granules, of small plagioclasic crystals quite totally sericitized, of biotite and muscovite in quite equivalent quantity, scattered and grouped in lepidoblastic beds.

The ferriferous segregations are abundant, chiefly along micaceous beds. In this contexture staurolite poikiloblasts of medium dimensions are noticeable. They are full of quartzous inclusions in which $2V = +87°$ and there is a light pleochroism in the folowing colours: N_p = light-yellow, N_m = rose-yellow, N_g = colourless.

61 AE-64. - Metadiorite. *East of Kangurchi.*

A rock with inequigranular, mosaic texture and some rare idiomorphic crystals. The plagioclase is the mineral which crystallizes in the largest grains (2-3 mm), generally strongly saussuritized, particularly in the most calcic central areas when these are zoned; quartz, on the other hand, is crystallized in transparent aggregates of smaller sizes with either a straight or slightly undulatory extinction; the aggregrates are welded together to form an irregular shaped net which surrounds the plagioclase crystals. Remnants of biotite flakes are rare, while small chloritic clusters are common; their random disposition indicates that they crystallized in a static environment. Epidote in the zoisite and pistacite varieties is an accessory.

61 AD-18. - Gneiss granite. *Upstream from Zebak* (*Sanglik valley*).

A rock with a mosaic equigranular texture, without any definite orientation, which can be seen indistinctly in the confused arrangement of the micaceous bands. The most abundant constituent is plagioclase of the albite-oligoclase variety; it is rarely twinned, and regularly shows a saussuritic grid. There are smaller amounts of K-feldspar with an alteration of the kaolinitic type, and the quartz shows straight extinction.

61 AD-19. - Quartz monzonite. *At the buck of Zebak.*

A rock with a hypidiomorphic granular texture showing plagioclase and biotite idiomorphic to quartz and K-feldspar. There is no distinctive texture. The rock seems to originate from the recrystallization of a finer-grained

rock, of which traces are preserved in a few parts of the thin section, and in a few crystals of plagioclase. The plagioclase is closely twinned, with twinning of the albite or albite-Carlsbad laws; the maximum angle of extinction measured in symmetric zones is 15°, which corresponds to an An composition of 35%. The K-feldspar has clear post-crystalline deformation with a grid structure of microcline type. The quartz is intensely fractured, but with a straight extinction. In the largest fractures, sparry calcite occurs.

β. DESCRIPTION OF THE SPECIMENS OF METAMORPHIC AND PLUTONIC ROCKS FROM THE LAKE SHIWA AREA (1).

61 AP-11. - Granite. *To the west of Kotal-i-Kurang, at bottom of the Nakhshir Par valley.*

The rock is a massive, slightly porphyritic microcline granite; like the samples of granodiorite collected from the intrusive bodies outcropping along the bottom of the Nakhshir Par valley this unique granite sample is weathered: the plagioclase is extensively sericitized and in place of the original biotite only chlorite occurs as large flakes containing sagenitic rutile and intralamellar laminae of muscovite. Microcline, showing well developed cross-hatched twinning, is very poor in perthites. Myrmechite is rather frequent. Among the accessories allanite is noteworthy, occurring as well developed and zoned crystals within plagioclase.

61 AP-12. - Hornfels. *Bottom of the Nakhshir Par valley, 3 km downstream from Kotal-i-Kurang.*

The rock belongs to the group of thermally metamorphosed schist of pelitic origin collected in the nearest contact with granodiorite in the Nakhshir Par valley (samples 61 AP-12, 12a, 14a, 14b, 14c). The rock is fine-grained, well foliated, dark grey in colour; it contains light rod-shaped volumes with lenticular section and measuring a few centimetres in lenghth which give way to protuberances on the schistosity planes. The aluminum silica-

(1) The descriptions of the samples is arranged in progressive order of the labels.

tes, that are, sillimanite (both fibrolite and sillimanite as small squat prisms), andalusite and kyanite occurs exclusively within these volumes, except sillimanite which also composes short and narrow streaks parallel to the foliation and contiguous laterally to the rod-shaped volumes. Muscovite, quartz, plagioclase and fine-grained staurolite also occur within the rod-shaped volumes. By textural and mineralogical features, compared with other occurrences of aluminum silicates in contact schist from the Nakhshir valley, the rod-shaped volumes are interpreted as relict forms of columnar andalusite. The groundmass of the rock is composed of quartz, biotite, muscovite staurolite and garnet, the latter two minerals occurring in small amount as moderately developed idioblasts. Additional minerals are apatite, zircon, ilmenite, tourmaline and graphite.

61 AP-12a. - Hornfels. *Bottom of Nakhshir Par valley, 3 km downstream from Kotal-i-Kurang.*

The distinctive feature of this rock is the occurrence of square or cruciform-outlined squat volumes, about 2 cm in size, which are referred to original andalusite porphyroblasts undergone a rather complex alteration process as results by their mineral composition and texture. In these volumes the following minerals occur in in decreasing proportions: muscovite, kyanite, staurolite, quartz, andalusite, plagioclase, sillimanite and fibrolite, mostly with variable ratios from point to point within each volume. The groundmass, very rich of dusty graphite, is foliated with undulating schistosity. In it quartz and biotite, toghether with graphite, are the chief components, garnet, and staurolite and muscovite occur in subordinate amounts, while fibrolite is found only in the groundmass in the nearest zone around the square and cruciform-outlined volumes. Garnet and staurolite are slightly porphyroblastic.

61 AP-13. - Hornfels. *Bottom of the Nakhshir Par valley.*

The rock is similar in hand specimen to the sample 61 AP-12, but does not contain the characteristic rod-shaped volumes found in it, being very uniform in texture. Reflecting the megascopical features no trace of aluminum silicates are found in this sample. The mineral assemblage and texture are similar to those found in the groundmass of sample 61 AP-12.

61 AP-13a. - Muscovite-biotite schist. *Bottom of Nakhshir Par valley.*

This is the rock with the simplest mineralagy among the schists surrounding the igneous bodies outcropping in Nakhshir Par valley. The rock is composed of rather irregularly alternating dark and light bands, measuring a few millimetres across. The dark bands are composed of a medium fine-grained aggregate of quartz and biotite with moderately oriented structure; in the light bands only muscovite occurs as aggregates with decussate structure. Oligoclase, tourmaline and opaque minerals occur in addition in the dark bands.

61 AP-14a. - Hornfels. *Bottom of Nakhshir Par valley, 3 km downstream from Kotal-i-Kurang.*

The rock is similar to sample 61 AP-12a, particularly in mineralogy and texture of the groundmass. A lesser graphite content is however found in it. The andalusite structural relics, occurring as square and cruciform-outlined volumes are more frequent and more simple in mineralogy in comparison with sample 61 AP-12a. They are, in fact, composed chiefly by kyanite and in subordinate amount by muscovite; scarce staurolite also occurs, while some fibrolite is found only in the nearest zone around these volumes.

61 AP-14b. - Hornfels. *Bottom of Nakhshir Par valley, 3 km downstream from Kotal-i-Kurang.*

This rock too differs from sample 61 AP-12a essentially in the features exhibited by the andalusite structural relics. In this sample they are rather rare and of lesser size, about 0,5-0,7 mm, and are composed of muscovite, kyanite and or a discrete amount of staurolite. Also in the groundmass staurolite occurs in greater proportion than in sample 61 AP-12a.

61 AP-14c. - Hornfels. *Bottom of Nakhshir Par valley, 3 km downstream from Kotal-i-Kurang.*

The rock, medium fine-grained, is the richest both in graphite and biotite among the contact schist from the Nakhshir Par valley, so that in hand speciment it shows black colour and an appreciable luster. The structure of the rock is foliated and finely folded; the probable andalusite relics occur

as slightly rotated square-outlined volumes about half a centimetre in size. Actually they are composed of muscovite and subordinately of staurolite and kyanite. Andalusite, referred to a younger generation, appears to have grown near the border of square-outlined areas toward the groundmass as poikiloblasts; nearby some sillimanite occur. In the groundmass of the rock biotite is abundant and occurs as well developed flakes, brownish-red in colour, oriented either parallel either, the larger ones transverse to the schistosity. Garnet occurs as small porphyroblasts with dusty cores.

61 AP-15. - Granodiorite. *To the west of Kotal-i-Kurang, at bottom of the Nakhshir Par valley.*

The rock is massive, coarse-grained and slightly porphyritic in structure. It is composed essentially of andesine (37-30% An), quartz, perthite-poor microcline, biotite and scarce hornblende. The plagioclase crystals are often bordered by narrow more albite-rich rims (18-10% An) particularly at contact with potash feldspar. Replacement antiperthite are occasionally found. The texture of the rock is hypidiomorphic granular; imprints of weak cataclasis are shown both by the occurrence of quartz as granoblastic aggregates of strained grains and by fractures in feldspars, which are filled with albite, microcline and quartz and give way to sharply limited intersecting veins. These veins are cut by younger veins composed of clinozoisite. Clinozoisite is also found replacing biotite toghether with albite and microcline.

61 AP-16. - Granodiorite. *To the east of Kotal-i-Kurang.*

The rock is massive, coarse-grained and contains scattered schlieren, measuring a few centimetres, with fine grain size and dark grey in colour in which rare larger plagioclase crystals are recognizable with naked eyes. In comparison with other granodiorite samples (61 AP-17/26 and 61 AP-15) the rock here described is distinguished mineralogically by a rather lower content in potash feldspar and the occurrence of more hornblende among the coloured components. The mineral assemblage is: plagioclase (actually saussuritized), quartz, nonperthitic potash feldspar, biotite and hornblende. Accessory minerals are apatite, zircon and sphene. The texture is hypidiomorphic granular; the interstitial quartz shows a mosaic texture. Transforma-

tions due to weathering are only shown by plagioclase and biotite, while the alkali feldspar and the hornblende are fresh; the latter appears to have been largely replaced by biotite. The dark schlieren are composed of hornblende-biotite microdiorite and contain more fresh plagioclase of composition ranging from 30 to 38% An.

61 AP-17/1. - Medium-grained banded gneiss. *Saddle between Amu Darya valley and Shiwa Lake, above Arakht.*

The rock shows a rather poorly developed banding at the scale of about 1 cm; small plagioclase eyes are visible in hand specimen. The essential components are plagioclase (24-26% An), quartz, potash feldspar orthoclase, with $2V\alpha = 50°$) and biotite. Additional minerals are apatite, zircon and allanite. The plagioclase is moderately deformed, usually albite, or, more rarely, albite and pericline twinned, and inclusion-free except for some quartz drops. The potash feldspar, non-perthitic and untwinned, occurs either as large anhedral crystals of the same size than plagioclase, or as small interstitial patches. In the first case it is always surrounded by conspicuous myrmechite grains. Myrmechite also occurs rimming plagioclase crystals at contact with potash feldspar. The biotite is reddish-brown in colour and makes up narrow, undulating, discontinuous streaks.

61 AP-17/2. - Gneissose pegmatite. *Saddle between Amu Darya and Lake Shiwa, above Arakht.*

The sample comes from a pegmatoid occurring as large concordant lens about 50 cm thick within medium-grained banded gneiss of type described above (sample 61 AP-17/1). The rock is milky-white in colour and contains scattered dark biotite-rich nest and oriented trails. The composing feldspar is chiefly perthite-poor orthoclase showing $2V\alpha = 53°$-$54°$; slightly sericitized plagioclase occurs in subordinate amount. Also quartz is rather scarce and irregularly distributed ad medium-grained crystals showing strongly undulose extinction. Fine-grained aggregates, composed of plagioclase (oligoclase 25% An), myrmechite and quartz are often interposed between adjacent micaceous trails. The biotite is reddish in colour and partially chloritized.

61 AP-17/3. - Fine grained garnet-bearing banded gneiss. *Along the slope between Lake Shiwa and the saddle above Arakht.*

The rock is representative of darker bands occuring among banded gneisses of granitoid composition. It is fine-grained and finely (mm) banded; the thin lighter and darker bands alternate rather irregularly; few feldspar eyes, some millimetres in size, are developed along the light bands.

The darker bands seen under the microscope are composed of rougly oriented and often frayed flakes of dark reddish-brown biotite and of irregular small grains of quartz and plagioclase. In the lighter bands plagioclase (30-26% An) is prominent. The feldspar is always twinned (albite and pericline), slightly deformed, as shown by bending of twinning lamellae and by veins filled with fine-grained quartz, myrmechite and biotite, and sometimes contains replacement perthites of potash feldspar. Quartz occurs as fine-grained granoblastic aggregates of small particles showing jagged outlines. Perthite-free orthoclase ($2V^{\alpha} = 38°\text{-}50°$) occurs either as poorly developed interstitial patches and films or, rarely, as larger grains at centre of lighter bands. Myrmechite borders are found around the plagioclase at the contact with orthoclase. Thin borders of untwinned albite also occur instead of myrmechite. Garnet is found within light bands as irregularly shaped scattered grains poikilitically including plagioclase, quartz and green biotite. The other additional minerals are apatite, allanite, zircon and iron oxides.

61 AP-17/4. - Amphibolite (metagabbro). *Along the slope between Lake Shiwa and the saddle above Arakht.*

The sample belongs to the less altered basic rock found in agmatites occurring in the migmatite complex of the Shiwa Lake area. The rock is almost massive in structure and medium to fine-grained. It is essentially composed of an equigranular aggregate of anhedral crystals of green-brown hornblende and plagioclase. The plagioclase shows moderate normal zoning (43-27% An). Biotite, quartz, Fe-Ti oxides, clinopyroxene, garnet, apatite and zircon occur in subordinate amount; sphene of secondary origin after ilmenite is also found. Both garnet and pyroxene (augite showing $2V\gamma = 56°\text{-}57°$ $c/\gamma = 44°$) are very scarce: the former occurs as largely poikilitic irregular grains, the latter is included in hornblende as relics. On ac-

count of both mineralogical and textural features the rock can be ascribed to a microgabbro or microdiorite as parental material.

61 AP-17/5. - Garnetiferous biotite amphibolite. *Along the slope between Lake Shiwa and the saddle above Arakit.*

The rock belongs to the heterogeneous banded gneisses occuring near the agmatite complex from which the above-described amphibolite (61 AP-17/4) comes. The rock was sampled from a dark band near the contact with a pegmatoid one. In hand speciment it is dark grey in colour, medium to coarse-grained and mostly massive. A slightly oriented structure results from the alignement of garnet granoblast and flattened light coloured patches. The mineral assemblage is composed of brown hornblende, plagioclase (27-28% An), garnet, biotite and quartz. Additional minerals are Fe-Ti oxides (mainly ilmenite), apatite and zircon. The garnet is rosy coloured and poikiloblastic, including almost all the other minerals as scattered small grains. The biotite occurs as large unoriented flakes showing a strong pleochroism ($\alpha =$ honey-yellow; β and $\gamma =$ dark reddish-brown). Quartz occurs either as granoblasts of medium size or as drops included in plagioclase. Unlike most of the banded gneisses the rock does not show any sign of post-crystalline deformation in its minerals.

61 AP-17/6. - Leucocratic biotite-plagioclase gneiss. *Eastern side of the inlet along the northern coast of Lake Shiwa.*

The rock is representative of the most leucocratic plagioclase gneiss occuring within the migmatite complex of the Lake Shiwa area. It is medium-grained and shows a gneissose, vaguely banded structure; plagioclase individuals are clearly recognizable in hand specimen. The larger plagioclases always occur as single, unoriented crystals poor in inclusions and twinned according to the albite and pericline laws; they are oligoclase-andesine in composition (30-32% An) and slightly zoned (with reverse zoning). The groundmass is composed of quartz, plagioclase as grains of small size and biotite, the later occurring as oriented and well developed flakes showing reddish-brown colour. Potash feldspar is present in very scarce amount both in groundmass and included within larger plagioclases. The accessory minerals are apatite, zircon and allanite.

61 AP-17/7. - Hornblende-biotite banded gneiss. *Western side of the inlet along the northern coast of Lake Shiwa.*

The rock, medium fine-grained and very poor in coloured minerals, shows banding at the scale of a few millimetres to 1-2 cm and a strongly oriented structure, both macroscopically and under the microscope; in the latter case, in fact, not only biotite and hornblende appear oriented, but also the colourless minerals are seen occuring as ribbon (quartz) or flattened lenses (quartz and potash feldspar) parallel to the gneissosity and banding. The dark bands are composed of biotite, showing brownish green pleochroism, green hornblende, plagioclase (26-27% An) and quartz and are rather continuous. The light bands are composed of oligoclase (27-24% An), quartz, orthoclase ($2V\alpha = 40°$) and some myrmechite. The potash feldspar is totally free of perthites and occur either as larger grains of the same size than plagioclase and anhedral with respect to it or, more frequently, as small interstitial grains or, in rare cases, as replacement perthite within plagioclase. Additional minerals of the rock are apatite, zircon, iron oxides and chlorite, the latter occuring either partially replacing biotite by alteration, either as small flakes scattered within the light bands.

61 AP-17/8. - Granitic augen gneiss. *Northern coast of Lake Shiwa.*

The rock has a rather poorly developed porphyroblastic gneissose structure and granitic mineral composition, being composed essentially of potash feldspar (perthite-poor orthoclase showing $2V\alpha = 56°$), oligoclase (23-25% An) and quartz in almost equal amounts and of minor proportions of biotite and myrmechite. Additional minerals are zircon, apatite and allanite. The augen structure results from the occurrence of larger crystals of orthoclase and, less frequently, of oligoclase as well as of few quartz lenses within a fine-grained quartz-feldspathic groundmass. Myrmechite is apparent, both at borders of the larger potash feldspar individuals and in the groundmass. Albite, instead of myrmechite, often occurs at borders of small plagioclase crystals included in orthoclase. The fabric of the rock shows effects of strain, above all in quartz and to a lesser extent in plagioclase.

61 AP-17/9. - Granitic augen gneiss. *Northern coast of Lake Shiwa.*

The rock has the same mineral composition than the granitic augen

gneiss 61 AP-17/8 but a decidely better developed augen structure. The eyes are quite variable in size from a few millimetres up to some centimetres and are irregularly distributed. The larger ones are composed of a few potash feldspar crystals (orthoclase going to transform to microcline as results from 2V values and twinning) generally bordered by myrmechite, and look like pegmatitic concretions; the less developed eyes are mostly single orthoclase ($2V\alpha = 53^{\circ} - 54^{\circ}$) and oligoclase (25% An) crystals. Among the accessories allanite is noteworthy, occuring as well developed individuals with perfect crystal habit.

61 AP-17/10. - Gneissose pegmatite. *Northern coast of Lake Shiwa.*

The rock is associated with augen gneiss of more leucocratic and coarser-grained type than the augen gneiss described above (sample 61 AP-17/9); gradational contacts in these rocks were observed in the field. In mineralogy and structure of this pegmatite is similar to sample 61 AP-17/2.

61 AP-17/11. - Medium-grained banded gneiss. *Northern coast of Lake Shiwa.*

This sample is a biotite-poor banded gneiss characterized by an even grain size and a neat banding at the scale of 1-2 cm. Apart its lesser content in biotite and the total absence of feldspathic augen the rock is similar to the banded gneiss 61 AP-17/1. Another distinctive feature with respect to sample 61 AP-17/1 is the occurrence within potash feldspar grains, mostly untwinned and showing axial angle of orthoclase, of shaded patches characterized by the typical cross-hatched twinning of microcline.

61 AP-17/12. - Biotite-rich gneiss. *Northern coast of Lake Shiwa.*

The sample here described is the richest in biotite and that possessing the most fine grain size in the group of plagioclase gneiss which could be examined (samples 61-AP/6, /12, /13). The rock is dark grey coloured in hand specimen and shows a strong foliation. It is composed essentially of about 50% andesine (33-35% An) and of quartz and biotite in equal amounts. Additional minerals, represented by apatite, iron oxides and zircon, occur in much greater proportion than in the other plagioclase gneisses.

61 AP-17/13. - Biotite-plagioclase-quartz gneiss. *Northern coast of Lake Shiwa.*

The rock, medium fine-grained and slightly porphyroblastic, grades in the field to the more biotite rich plagioclase gneiss 61 AP-17/12. In texture and biotite content the sample is intermediate between the above named sample and the most leucocratic plagioclase gneiss (sample 61 AP-17/6).

61 AP-17/14. - Biotite-amphibole schist. *Northern coast Lake Shiwa.*

The rock is fine-grained, dark greenish-grey in colour and weakly foliated. In thin section two S-surfaces, lying at low angle with each other, are recognized, the chief put into evidence by parallel arrangement of amphibole slender prisms, the latter defined by oriented biotite flakes. The mineral association is hornblende, plagioclase (30-28% An) biotite, sphene and quartz. Apatite and Fe-Ti oxides occur in addition, toghether with some potash feldspar, the latter being present as replacement perthites or veins filling fractures within plagioclase. The hornblende, mostly occurring as large poikilitic prisms with porphyroblastic appearance, is strongly coloured and moderately zoned, the absorption colours, for γ, changing from bottle-green at the core of crystals to bright blue-green at borders of larger prisms or in smaller grains. The biotite, brown green in colour is altered to a little extent to chlorite and epidote. Sphene is abundant, particularly in association with biotite, and well crystallized. There is evidence, in the whole rock fabric, of a late dynamic metamorphism to which perhaps only biotite crystallization survived.

61 AP-17/15. - Blastomylonitic augen gneiss. *Northern coast of Lake Shiwa.*

The rock belongs to the group of cataclastically deformed augen gneiss occurring near Lake Shiwa and is representative of type showing relatively moderate deformation and diaphtoritic changes of minerals (plagioclase and biotite). It is coarse-grained and greenish-white in colour. Perthite-poor-microcline, sericitized plagioclase and quartz are the chief components and occur in almost equal amount; scarce chlorite, accompanied by sphene, iron oxides and white mica and evidently derived from biotite, is also present.

61 AP-17/16. - Blastomylonitic augen gneiss. *Northern coast of Lake Shiwa.*

The rock belongs to the group of augen gneiss, granodioritic in mineral composition, and of aplites cataclastically deformed at high temperature occurring near Lake Shiwa. It shows a well developed augen structure, as contains feldspar eyes up to 0.5 cm in size set in a fine-grained groundmass composed of finely granulated plagioclase, quartz, microcline and myrmekite and partially wrapped around by pseudoschistose quartz layers and biotite streaks. The larger feldspars are either plagioclase (30% An) porphyroclasts either microcline (lacking or very poor in perthites) phenoblasts showing features of porphyroblasts. The additional minerals are represented by apatite, ilmenite and zircon.

61 AP-17/17. - Fine-grained banded gnesis. *Northern coast of Lake Shiwa.*

The rock is similar in texture and mineral composition to the garnet-bearing banded gneiss 61 AP-17/13. Garnet is lacking, and a somewhat greater proportions of potash feldspar and myrmekite occur.

61 AP-17/18. - Metagabbro. *Northern coast of Lake Shiwa.*

The rock is medium fine-grained, greenish-black in colour and almost massive. Under the microscope a sub-ophitic texture is still recognizable, plagioclase occurring as mostly subhedral, randomly oriented laths, amphibole, which is the other essential component of the rock, being present as subahedral to anhedral crystals. The plagioclase shows zoning (67-40% An) except in some individuals with granoblastic appearance which have an uniform andesine composition (38-40% An). The amphibole is a green hornblende and is partly replaced by biotite. Fe-Ti oxides and partite occur as primary accessories. Sphene, chlorite, quartz and potash feldspar, all of secondary origin, are found in little amount mostly filling fractures.

61 AP-17/19. - Blastomylonitic pegmatite. *Northern coast of Lake Shiwa.*

The rock, medium-grained and white in colour, shows a distinct foliation essentially due to quartz pseudoschistose layers. The mineral assemblage is composed of plagioclase (with about 10% An), microcline, microperthite and quartz; blue-green tourmaline, garnet, albite (an almost pure term) myrmekite and white mica occur in addition. The feldspar, as well as tourma-

line and garnet, are fractured and cemented by quartz and, more rarely, by albite and white mica. Garnet shows diaphtoritic changes to chlorite. On the base of the mineralogical and textural features the rock can be interpreted as deriving, by dynamic metamorphism under low temperature conditions, from a pegmatite or an aplite-pegmatite.

61 AP-17/20. - Blastomylonitic augen gneiss. *Northern coast of Lake Shiwa.*

The rock is rather similar to the augen gneiss 61 AP-17/16, differing from it mostly in texture, in showing a more advanced stage of deformation, which produced a more marked foliation and a stronger cataclasis of the feldspar eyes, particularly in plagioclase. Some mineralogical differences, partly related to stronger cataclasis, are also noticed: the larger plagioclases are zoned (37-30% An), the microcline phenoblasts are richer in perthites and among the accessories sphene occurs, while opaque minerals are lacking.

61 AP-17/21. - Garnet-sillimanite schist. *Northern coast of Lake Shiwa.*

The rock was sampled from a raft interposed, probably with tectonic contacts, within augen gneiss. It is dark grey in colour fine-grained, moderately foliated and finely zoned in consequence of a still preserved bedding.

The mineral assemblage of the rock is composed of quartz, biotite, muscovite, sillimanite and garnet, the latter occuring in little amount. Additional minerals are tourmaline, zircon, apatite and iron oxides. Effects of cataclasis are shown by quartz and garnet, subordinately by micas and sillimanite. This one is the fibrolite variety and occurs in considerable proportions as bundles of fine needles distributed everywhere; some larger squat sillimanite prisms, probably formed by recrystallization of fibrolite, also occur. This schist is interpreted as a thermally metamorphosed pelitic rock.

61 AP-17/22. - Blastomylonitic augen gneiss. *Northern coast of Lake Shiwa, near the left hand side of the Darrah-i-Kotal valley.*

The rock middle coarse-grained and greenish-white in colour, is slightly schistose (pseudoschistose); also the augen structure is poorly marked in hand specimen, with the exception of some larger potash feldspar eyes which

are well recognizable for their pinkish-white colour. The rock is composed of strongly deformed feldspar porphyroclast of microcline microperthite and of plagioclase (30% An) embedded in a fine-grained matrix made up of stretched quartz grains and of minor amounts of plagioclase and microcline. The content in coloured minerals is scarce, like in other blastomylonitic augen gneiss having a comparable potash feldspar/plagioclase ratio (61 AP-17/15, 61 AP-17/24). Actually they are represented by chlorite, Fe-Ti oxides and sphene pseudomorphous on biotite as is argued by texture and survival of pleochroic halos within chlorite.

61 AP-17/23. - Metagabbro. *Northern coast of Lake Shiwa, near the left hand side of the Darrah-i-Kotal valley.*

The rock, coarse-grained and massive, has a spotted appearance due to the separation of colourless and coloured minerals as polycrystalline aggregates. The essential mineral association is made up of plagioclase (52-30% An) and hornblende; biotite, sphene and quartz are found in minor amounts. Ilmenite, apatite and scarce thulite occur as primary (i.e. of magmatic origin) accessories. Amygdales composed of quartz, chlorite and/or actinolite occur. The texture of the rock is variable from point to point: the amphibole, a green hornblende, mostly occurs as aggregates of a few large randomly oriented prisms often showing schiller structure and including scattered biotite flakes and sphene grains, while plagioclase either occurs as well developed and fractured single crystals, turbid due to alteration, or makes up aggregates of small granoblasts with sutured boundaries. With respect to origin the rock is interpreted as a gabbro (or diorite) subjected to an essentially dynamic metamorphism.

61 AP-17/24. - Blastomylonitic augen gneiss. *Left hand side of the Darrah-i-Kotal valley.*

This rock has many analogies with samples 61 AP-17/15 and 61 AP-17/22; like these it shows the imprint of strong (more intense than in the latter samples) dynamic metamorphism accompanied by recrystallization of quartz alone, toghether with some alkali feldspar, and diaphtoritic changes of other minerals (biotite and plagioclase). A distinct feature of the rock here described is the frequent occurrence of intersecting veins cross-cutting both

the feldspar porphyroclasts and the quartz pseudoschistose layer, which point out a late cataclastic action. The veins are filled with quartz, chlorite, albite and, within potash feldspar eyes, with granular perthite-free clear microcline.

61 AP-17/25. - Blastomylonitic aplite. *Left hand side of the Darrah-i-Kotal valley.*

The rock, whitish in colour and medium fine-grained, possesses a well developed foliation due to the parallel arrangement of muscovite flakes making up thin layers and to quartz pseudoschistose strips. Its mineral assemblage is composed of oligoclase (28% An), orthoclase ($2V\alpha = 52°$), partly transformed to microcline, quartz and muscovite. Garnet, biotite (both chloritized p.p.), apatite, zircon and albite, the latter occurring as thin veins in fractures, are present in adddition.

61 AP-17/26. - Cataclastic granodiorite. *Right hand side of Ab Zijan valley.*

The rock has a distinct augen stucture due to the occurrence of rounded feldspar individuals up to 0,5 cm in size within a dark, fine-grained weakly foliated groundmass. In structure, the rock is intermediate between massive granodiorite of the adjacent igneous bodies (samples 61 AP-16) and the biotite-bearing blastomylonitic augen gneisses (samples 61 AP-17/16 and 61 AP-17/20). It is composed of oligoclase (with composition ranging due to zoning, from 23% An to 8% An), microcline microperthite, quartz and biotite. Some myrmekite is found near potash feldspar; albite and non perthitic microcline are found in veins. Zircon, apatite, tourmaline and sphene, the latter secondary after biotite, occur in addition. There is textural evidence of cataclasis by deformations in the larger feldspar. Quartz, on the contrary, occurs mostly as granoblastic aggregates with mosaic texture which point out a recrystallization under static conditions.

61 AP-17/27. - Blastomylonitic garnet-biotite aplite. *Between Ab Zijan valley and Kotal-i-Kurang.*

The rock is medium fine-grained and whitish in colour except for sparse narrow and discontinuous strips made up of coloured minerals (garnet and

biotite). The colourless minerals are oligoclase (26-28% An) microcline microperthite and quartz. Notwithstanding intense textural changes related to cataclastic metamorphism (straining and crushing of grains, accompanied by recrystallization of quartz and of some albite) some features of an aplitic texture are still preserved.

γ. DESCRIPTION OF THE SPECIMENS OF METAMORPHIC AND PLUTONIC ROCKS FROM WAKHAN (1).

63 GB-4. - Fine-grained paragneiss. *Qala Wust.*

The rock is characterized by a minute aggregate of granoblastic quartz and micas, passing gradually to augenized elements of small dimensions, quartz and feldspar. The texture is highly schistose, with fairly continuous micaceous bands, and micaceous coatings throghout, especially around the individual augens. A rather dark biotite is predominant in small fragmentary flakes, and with abundant peripheral granulations, and also a certain quantity of fresh muscovite. The augens are mainly of plagioclase composition, occasionally with incipient saussuritic alterations, and often including particles of quartz. Sometimes they form small concretionary plates with microcline. The quartz augens are free from the blastic texture which characterizes the surrounding aggregate.

63 GE-6. - Orthogneiss. *Downstream from Qala Wust, sequences E.*

A rock of aplitic composition which appears to be affected by extreme recrystallization of quartz, by a certain schistose orientation of the rare micaceous components, and by a considerable neo-growth of muscovite. In the framework of the aplitic texture, crystals of microcline can be seen, and highly interpenetrated crystals of plagioclase, intermingled with the abundant quartz, with a highly undulatory extinction in mosaic form, and in ex-

(1) By F. Forcella. The descriptions of the samples are ranked in four classes, that is: sedimentary and light parametamorphic rocks, metamorphic rocks, plutonic rocks and volcanic rocks. Within the classes they are arranged in progressive order of the labels.

tended plates, according to the schistose orientation. In this framework, small diablastic micaceous groups are intermingled, and occasionally lines of tabular flakes of biotite and muscovite occur. Large tabular aggregates of muscovite, which have been affected by paracrystalline deformation are very fresh and well preserved, and are scattered in the granular matrix, occasionally enveloping the remains of quartz grains. Among the accessory minerals, a few tourmaline grains can be observed.

63 GD-7. - Fine-grained paragneiss with pegmatitic injections. *Babatangi valley: Sequence D, 160-185 m.*

The schistose portion is represented by a paragneiss with extremely small and homogeneous grains; it is rich in quartz, in regularly iso-orientated tabular lamellae of biotite, and has a small amount of oligoclase. In this groundmass, a few larger tabular flakes of muscovite are of late crystallization, and they are generally arranged without reference to the schistose orientation, and are also clearly poikiloblastic. Through a sharp contact, the rock changes to pegmatite zones with medium to large grains, the zones being essentially quartz-plagioclase. They are characterized by marked paracrystalline deformations in the plagioclase and quartz, and also by a certain arrangement of muscovite flakes in orientated bands. In general, recrystallized quartz is found in these bands.

63 GA-4. - Paragneiss with bands of quartz-plagioclase and biotite. *Valley east of Khandut, sequence A, 190-192 m.*

The thickest bands are composed of blastic quartz with sutured aggregates having undulatory extinction; the quartz is associated with numerous rounded plagioclase crystals, surrounded by kaolin. Thin discontinuous clusters of biotite are inserted between the feldspars and the quartz. The biotite is almost completely chloritized with frayed margins. The same micaceous aggregates occasionally become thich and unbroken; the biotite is better preserved, and forms lepidoblastic bands up to 5 mm in thickness. In these bands, quartz and feldspar elements exist in smaller quantities, together with a few crystals which have been completely transformed into sericite. In addition, a few grains of tourmaline can be seen, probably of detrital origin.

63 GE-3. - Micro-augen biotite gneiss. *Downstream from Qala Wust, sequence E.*

The rock is composed of a fine-grained grano-lepidoblastic aggregate of quartz, muscovite and biotite enclosing numerous feldspathic porphyroblast. In the granopidoblastic groundmass, the micaceous aggregates outline a close undulatory network, clearly moulded to the surface of the porphyroblasts. The latter are made up almost completely of plagioclase and of a few crystals of orthoclase; they present rounded xenomorphic shapes, with a high degree of normal zoning, and good examples of twinning, mainly according to the albite-pericline and albite-Carlsbad laws.

63 GE-8. - Microgranular biotite paragneiss. *Downstream from Qala Wust, sequence E.*

This rock has a fine-grained, granoblastic quartz-feldspar groundmass, with small orientated flakes of biotite. Quartz and feldspar are distributed homogeneously, with a slight prevalence of the first, the grains of which tend to be welded together along the plane of schistosity. The feldspars are represented by oligoclase. The biotite appears as isolated flakes of small dimensions, or as small orientated diablastic groups. Iron oxides, apatite and sphene can be observed as accessory minerals.

63 GE-4. - Augen biotite gneiss. *Downstream from Qala Wust, sequence E.*

This rock has a microgranoblastic groundmass of quarz-feldspar and biotite, which encloses large feldspathic porphyroblasts. In the matrix there are intermingled in almost equal amounts sodium plagioclases, potassic feldspars and quartz, often with myrmekitic and graphic concretions. Biotite forms thin diablastic bands, moulded to the surfaces of the porphyroblasts. A certain quantity of muscovite is associated with the biotite, and also chlorite of late genesis. The porphyroblasts appear in heterogeneous shapes and sizes, and are composed mainly of microcline-perthite and secondarily by plagioclase. The potassic feldspar is clearly post-plagioclase, which is reabsorbed and corroded. The potassic feldspar are surrounded by highly developed myrmekitic margins. All the porphyroblasts and especially those of the largest size appear fractured and distorted, and are occasionally traversed by veins of quartz.

63 GD-13. - Migmatitic banded gneiss. *Babatangi valley: sequence D, 275-425 m.*

The rock is characterized by bands of different composition, of which a few are of fine-grained quartz-plagioclase, others of aplitic type, besides large porphyroblasts of microcline. The fine-grained bands correspond to quartz-biotite paragneiss, with rare acid plagioclase, passing gradually to zones of an heterogeneous texture, in which the micas are gathered in lepidoblastic clusters, which are discontinuous and undulatory. Simultaneously, xenoblasts of microcline appear. The quartz is extensively recrystallized and forms in placed sutured plates of large dimensions, and also in bands which contain orientated micaceous traces. Other zones show a very fine-grained xenomorphic granular texture, and are composed mainly of individuals of microcline in juxtaposition, with a few interstitial flakes of muscovite and biotite. In the same zones, a few large porphyroblasts of microcline appear, obviously formed by the recrystallization and growth of the pre-existing individuals of the minute groundmass. They are accompanied by recently formed muscovite in large flakes, with paracrystalline mechanical deformation.

63 GN-1. - Microgranular metamorphic sandstone. *Kazdan.*

The rock maintains the original fine-grained clastic texture, on which is superimposed a certain orientation of the micaceous components. The clastic elements are mainly angular grains of quartz, and to a lesser degree sodium plagioclase and potassic feldspars among which can be seen crystals of perthite and microcline. The matrix is represented by abundant biotite, in small fibrous aggregates, by tabular blocks of muscovite, and by strings of usually obscure chlorite. Associated with the micas, there are also microgranoblastic forms of quartz, tending to increase along the planes of schistosity. Large detritals of iron oxides are numerous.

63 GN-8. - Microgranular metamorphic sandstone. *Kazdan.*

The rock is characterised by a fine-grained and very variable clastic texture, with disorientated micaceous components. Among the clastic elements, apart from the predominant quartz and feldspar, numerous fragments of quartzitic and graphitic phyllite can be observed. The matrix is almost completely composed of micaceous minerals, especially sericite and

chlorite. In addition, a few isolated flakes of biotite and fresh tabular flakes of muscovite, with paracrystalline deformation, can be seen. Small granules of iron minerals are scattered throughout.

63 GD-5. - Microgranular quartz-schist. *Babatangi valley: sequence D, 80-100 m.*

The bulk of the rock is composed of a very fine-grained and homogeneous granolepidoblastic matrix of quartz and biotite, with a markedly schistose texture.

The rock has a thinly banded texture which is differentiated by a variable graphitic content. In addition, bands of coarser granoblastic quartz; bands, usually lenticular, composed of late stage diablastic intergrowths of muscovite and compact aggregates of sericite are present.

63 GD-9. - Microgranular biotite quartz-schist. *Babatangi valley: sequence D, 160-185 m.*

The rock differs from GD-7 by the lack of poikiloblastic muscovite, and by a certain difference in the distribution of quartz and mica bands.

63 GD-2. - Graphitic biotite phyllite. *Babatangi valley: sequence D, 0-70 m.*

A very fine-grained rock, composed almost completely of granoblastic quartz, biotite, and abundant powdery graphitic material. The schistose orientation is marked also in the quartz, the granules of which are occasionally welded in bands or elements parallel with the planes of schistosity. The biotite is composed of thin flakes, in aggregates with a fibrous appearance. Iron oxides, granules of sphene, zircon and tourmaline can be observed as accessory minerals.

63 GA-1. - Microgranular epimetamorphic sandstone. *Valley east of Khandut: sequence A, 0-150 m.*

A fine-grained sandstone with sub-angular clastics, consisting almost entirely of quartz, with sericitic and carbonaceous cement. The granules are separated by a sericitic network, which is almost continuous, while the carbonaceous material is concentrated in undulating and anastomosing bands.

In addition, a few calcitic nests and few small isolated flakes of muscovite can be observed. Grains of iron minerals are abundant.

63 GC-4. - Granite. *Babatangi valley: 1 st. camp.*

A rock with a rather coarse ipidiomorphic granular matrix, composed mainly of potassic feldspar, quartz and plagioclase, with a small amount of biotite and muscovite of late growth. The feldspar appears in much greater quantity than the plagioclase, and is composed of microcline, microcline-perthite and perthite, occasionally with reticular growths and in a « chess-board » pattern with quartz. The plagioclase, smaller in size and tending to be idiomorphic, is composed of oligoclase with an albitic margin. Biotite appears in rather fresh tabular bloks. The muscovite forms large poikiloblasts, which grow at the contact, and also within the crystals of potassic feldspar.

63 GC-1. - Leucogranodiorite. *Babatangi valley: right-hand slope, 4000 m a.s.l.*

The rock has a quartz-feldspar matrix, with lamellar groups of biotite, almost completely chloritized. All the sialic components are large, with a clear tendency for the plagioclase to form idiomorphic macrocrystals which are enclosed in large plates of quartz with sutured margins. Smaller quantities of microcline and microcline-perthite are also clearly xenomorphic. All the constituents are affected by an intense cataclasis and a close network of fractures affects the whole rock. The feldspar, particularly along the fractures, shows abundant sericite, kaolinite and calcite alteration products. Occasionally the calcite is recrystallized in granoblastic veins, together with quartz.

63 GE-7. - Aplitic granite. *Downstream from Qala Wust, sequence E.*

The rock has a matrix of heterogeneous texture, composed almost entirely of quartz and feldspar crystals. Microgranular parts of aplitic appearance, composed mainly of microcline and concentrated in the interstices between the macrocrystals can be observed. The macrocrystals are xenomorphic orthoclase, in part perthitic, microcline and quartz aggregates. The myrmekitic and graphic concretions of quartz and potassic feldspar are

well developed. The plagioclase is an oligoclase with albite twinning, and is present in small quantities as small isolated crystals, occasionally very corroded by potassic feldspar. Muscovite is present in broad tabular flakes which are very fresh, occasionally with curved cleavage planes and occasionally poikilitic. The flakes are isolated or arranged along the fracture lines, which are filled with granoblastic quartz.

43 GD-4. - Migmatitic augen gneiss. *Babatangi valley: sequence D, 72-80 m.*

The rock is composed of an aggregate of quartz, plagioclase with an aplitic texture and muscovite, which envelop large feldspathic augens, large plates of quartz and broad flakes of muscovite. The fine-grained xenomorphic granular aggregate appears orientated in bands and lenses which have been displaced and invaded during the late growth of the porphyroblasts. The latter are composed mainly of microcline and to a lesser degree of acid plagioclase. They appear to have crystallized at the same time as the broad flakes of muscovite, and both show paracrystalline deformation. In addition, a few large crystals of shattered garnet with an idiomorphic appearance can be observed.

43 GD-8. - Quartzite. *Babatangi valley: sequence D, 160-185 m.*

The rock is composed entirely of large quartz plates with sutured contacts and occasionally with disturbed margins along which there is a filling of microgranular quartz and very small amounts of sericite and ferriferous granules. The whole rock appears fractured, and the quartz presents a highly undulatory extinction.

63 GD-15. - Granodiorite. *Babatangi valley: sequence D, 425-625 m.*

The rock shows abundant large crystals of oligoclase and xenomorphic plates of albite. Between these large crystals, there is a matrix of granolepidoblastic quartz aggregates, muscovite and biotite, which is sometimes chloritized. They are rich in small granules of sphene, with a few rare prismatic crystals of apatite. The biotite present in these aggregates tends to form diablastic groups, while the size of the flakes increases notably. The crystals of microcline-perthite include very abundant corroded fragments

of quartz, plagioclase, muscovite and biotite. In them, a few plagioclase crystals maintain a prismatic appearance, and form myrmekitic aggregates at the contact. The albite plates appear to have intergrown with microcline, which is coarsely mottled. The microcline passes gradually at the margins into the microgranular microcline belonging to the plates with an aplitic texture. The plates of antiperthite appear to be covered by saussuritic alteration products, mainly sericite, muscovite and zoisite. On the other hand, the large idiomorphic crystals of oligoclase appear rather transparent, with fine albite-Carlsbad and albite-pericline twinning.

63 GD-16. - Quartz diorite. *Babatangi valley*: *sequence D, 675-1025 m.*

This rock has a coarse, ipidiomorphic granular texture, and is made up of quartz, feldspars, biotite and a small percentage of alteration and accessory minerals. Among the sialic elements, quartz and plagioclase dominate, and both are of greater dimensions than the microcline, which appears in isolated xenomorphic plates, and also in microgranular interstitial groups. The plagioclase tends to form idiomorphic prisms, is moderately zoned, and shows extended, and also complex twinning. Generally, it is rather fresh and presents small saussuritic nests, and also small sericitic flakes, enclosed along some cleavage planes. The biotite appears in moderate quantity as groups of random interlacing flakes, which occasionally have poorly developed basal cleavage. Small granules of sphene and rutile are present as accessory minerals.

63 GD-17. - Granodiorite. *Babatangi valley*: *sequence D, 1025-1625 m.*

Very large prismatic crystals of microcline are enclosed in a coarse-grained matrix of quartz, plagioclase and micas. The idiomorphic plagioclase is oligoclase, is zoned and is often full of small flakes of muscovite. In addition, biotite appears abundantly in large tabular flakes, and form host to numerous crystals of zircon and apatite. Finally, late stage muscovite occurs, in abundant large flakes which are mainly isolated poikilitic or with crenellate outlines. The muscovite, together with granoblastic quartz, appears also along veins which carry in particular large feldspathic crystals. The latter, sometimes twinned according to the Carlsbad law, appear full of plagioclase crystals with aplitic reaction margins, flaky granules and stringers of quartz and isolated micaceous flakes.

63 GD-19. - Granodiorite. *Babatangi valley: sequence D, 1625-1900 m.*

The rock appears similar in texture to the preceding (GD-17) with sligth differences in composition, degree of fracturing and distribution of limonitic alteration products. The large crystals are perthite, and are poikilitic and twinned according to the Carlsbad law. Only rare muscovite occurs.

63 GB-3. - Blastomylonitic granitoid gneiss. *Khandut.*

Large feldspathic crystalloclasts are enclosed in a schistose matrix of biotite, muscovite and microgranoblastic quartz. The rock shows mylonite surfaces and successive fracturing, corresponding to the schistose bands in which closely packed and discoloured biotite appears. The muscovite, although fresher, shows marked contortions. The feldspathic crystalloclasts appear highly laminated and rounded on contact with the micaceous quartz clusters. They are sometimes cut by clear fractures, but retain straight extinction. Orthoclase and microcline are the most abundant, and oligoclase crystals occur in a smaller number.

63 GE-2. - Blastomylonitic granitoid gneiss. *Downstream from Qala Wust, sequence E.*

The rock shows a marked orientated texture, due to quartz bands, micaceous bands mixed with alteration products and feldspathic crystalloclasts, which also tend to group together in concordant lenses. The most abundant and homogeneous mass is microgranoblastic quartz, with elements clearly originating from mylonitization of pre-existing crystals. These are often elongated and joined in the form of clusters which follow the margins of the crystalloclasts. The micaceous bands are very fresh, and also include large flakes of muscovite which are strongly twisted and occasionally shattered and displaced. The micas are mainly enveloped in sericitic alteration aggregates. In addition, rare isolated biotite flakes can be seen. Among the crystalloclasts unequal quantity of oligoclase and orthoclase can be observed. These have been affected by intense fracturing which can sometimes be seen in the plagioclase as simple bending, while in the potassic feldspar, it always appears as fine fracturing, up to com-

plete shattering of the crystals. In the largest crystalloclasts of orthoclase, poikilitic inclusions of plagioclase are often present.

63 GD-3. - Cataclastic-mylonitic quartz. *Babatangi valley: sequence D, 70-72 m.*

The rock is composed exclusively of highly cataclastic to mylonitic quartz. Large crystals occur, which have been affected by strong fracturing and cemented by a matrix which consists of finely crystalline quartz. The crystalloclasts often appear displaced along the ultramylonite bands, in which case they assume a flow texture.

63 GD-12. - Leucogranite. *Babatangi valley: sequence D, 275-425 m.*

The rock is characterised by a mainly sialic matrix and hypidiomorphic granular texture. A very small aggregate of aplitic appearance was observed; composed of microcline and quartz, amongst which large, sub-rounded crystals of albite occur, together with clearly xenomorphic crystals of microcline. The albite is full of inclusions of muscovite, zoisite and quartz; its twinning lamellae often appear curved. Quartz also appears as isolated crystals of larger size and fractured appearance, occasionally in elongate stringers; in this case, it always shows undulatory extinction. The muscovite passes from pellet-like aggregates of small frayed flakes to diablastic groups ranging up to fresh isolated flakes of large dimensions. Microgranular nests of iron oxides are very rare.

63 GD-14. - Garnetiferous migmatitic gneiss. *Babatangi valley: sequence D, 275-425 m.*

The rock is poorly schistose, and has a poorly developed granolepidoblastic texture. It is very sialic in composition, being almost entirely quartz-feldspathic, with a small amounto f mica, mainly muscovite. Parts of the rock are composed of minute grains forming an aplitic and micropegmatitic texture. These are the result of closely interpenetrated quartz and microcline, which have been oriented parallel to the lamellar bands. The

matrix is interrupted by the appearance of metablasts of microcline of larger size, which substitute the first segregation of microgranular microcline without disturbing the quartz granules which occur in it. In addition, augen of albite appear; these are very fresh and full of orientated inclusions, especially muscovite. They are generally grouped in zones independent of the microcline. The relationships between the two types of feldspathic metablasts are not clear. The quartz, especially in the bands which are rich in metablasts, forms large plates and bands with undulatory extinction. The micaceous bands are thin, but persistent, and are accompanied by crystals of garnet and epidote.

63 GE-11. - Cataclastic quartz diorite. *Between Ishmara and Abgash, sequence E.*

This rock is medium-grained with a massive texture. The main constituents are a plagioclase, zoned oligoclase, which has conspicuous polysynthetic and complex twinning, quartz and biotite. The accessory minerals include microcline and hornblende. Strong fracturing, accompanied by significant mineralogical changes, affects the rock. The plagioclases are surrounded by kaolinitic products, are fractured and occasionally have decidedly curved lamellar twinning. Biotite is almost completely chloritized, as is also much of the hornblende. Nests, veins and grids of calcite are spread extensively both within and on the margins of the minerals described. Quartz has a marked undulatory extinction. Ilmenitic skeletons and prisms of apatite and rutile are present as accessory minerals.

63 GC-3. - Leucoquartzmonzonitic aplite. *Babatangi valley: right-hand slope, 4000 m a.s.l.*

The rock is composed of a quartz-feldspar matrix with a xenomorphic, very fine-grained, granular homogeneous texture. The micaceous elements are reduced to a few small isolated flakes of muscovite and more or less chloritized biotite. The sialic constituents are represented in almost equal quantities by quartz, microcline and oligoclase, the latter being often surrounded by an albite margin. These constituents are distributed in a particularly regular and uniform manner, without reciprocal intergrowths or interpenetrations, and simulate a mosaic texture in some parts.

63 GE-1. - Blastomylonitic muscovite orthogneiss. *Downstream from Qala Wust. Sequence E.*

The rock is characterised by a very marked granolepidoclastic texture, and by an augen-schistose texture which is also marked. Feldspathic crystals are abundant and are highly curved, shattered and separate. They have acquired augenized and lenticular margins, in perfect concordance with the orientation of the quartz-mica bands. Single large crystals occur, or groups of compressed crystals in justaposition, similar to the fragments of a breccia. The fractures in the crystals and the intercrystalline spaces are often filled with calcite. The feldspars are mainly oligoclase and microcline. Numerous large isolated flakes of muscovite are affected in the same way. The matrix enclosing the large crystals is made up of micaceous-quartz bands closely alternating and regularly iso-oriented. In these bands, the quartz has an extremely fine-grained granoblastic texture, imposed on a highly mylonitized mass, and the mica it closely mingled with it, in the form of thin nematoblastic aggregates of sericite. A few bands are rich in iron oxides.

63 GA-10. - Plagiotrachyte. *Valley east of Khandut: sequences A, 470-475* m.

This rock has a porphyritic holocrystalline texture of sialic composition, with a breccia-type texture. The groundmass is made up mainly of a plagioclase aggregate, with minute granophyric zones and zones with slightly larger grains, having an intersertal texture. Minute flakes of sericite and calcite grains are scattered irregularly among the plagioclases. Occasionally the calcite forms large spathic crystals, in which case it is preferably associated with mosaic quartz nests or veins. Highly limonitized iron oxides are generally associated with the calcite. The phenocrystals are oligoclase, and show no difference in composition when compared with those in the matrix. Either perfectly idiomorphic isolated grains or groups of irregular grains are found bound together by sericitic aggregates. Some small sericitic flakes are found inside the same phenocrystals throughout the rock.

63 GA-6. - Plagiotrachyte. *Valley east of Khandut: sequence A, 215-220 m.*

The rock is composed of a feldspathic aggregate, with an intersertal

texture, mixed with abundant calcite, either microgranular or spathic, and with nests of granoblastic quartz. The feldspar is represented by small idiomorphic colum-shaped prisms of oligoclase, highly zoned and ranging up to an albitic composition. Xenomorphic albite nests are also found isolated in the grids of the intersertal aggregate. Calcite occurs persistently and homogeneously in the intercrystalline spaces between the feldspars. Quartz has a more fragmented distribution.

63 GE-10. - Biotitic blastomylonitic orthogneiss. *Downstream from Qala Wust, sequence E.*

A fine-grained granolepidoblastic texture can be clearly observed in this rock, enclosing numerous feldspathic crystalloclasts. The cement is composed mainly of lamellar aggregates and pellets of biotite, scattered with small grains of sphene. The biotite is finely lamellar, ranging to fibrous, and occurs locally as large isolated flakes, bordered by grains of sphene. Microgranoblastic quartz lenses are associated with the biotite. The arrangement of these granolepidoblastic bands is clearly iso-oriented with close undulations around the crystalloclasts. In addition, micaceous bands can be seen, occurring along the fractures, oblique to the schistose orientation, in which mainly chloritized biotite appears. Many of these fractures cross and displace the crystalloclasts. The latter are composed of basic oligoclase crystals, which are generally shattered or have curved lamellar twinning and subrounded margins. Despite the fracturing, the alteration phenomena of the feldspars are limited.

63 GD-18. - Diorite. *Babatangi valley: sequence D, 1025-1625* m.

This is a massive medium-grained rock with a hypidiomorphic texture. The most notable feature is the abundance and idiomorphic prismatic appearance of a slightly pleochroic amphibole, light green and light brown in colour, occasionally completely chloritized and generally darkened by interlamellar segregations of uncertain nature. The optic characters indicate a hornblende. The sialic part is seen as a very compact plagioclase net, in which the single crystals occasionally have an elongated poor prismatic form, but has indefinite margins because of reciprocal interference. The plagioclase is oligoclase. There is no zoning, but the twinning is well deve-

loped, and is almost entirely in the albite or albite-Carlsbad laws. Parts of the plagioclase crystals are replaced by segregations of sericite, muscovite, quartz, epidotes and calcite, as a results of rather advanced saussuritization.

63 GD-6. - Fine-grained quartz schist. *Babatangi valley: sequence D, 100-160 m.*

An extremely homogeneous and fine-grained groundmass of quartz and micas can be seen, together with very fine grains, probably of a graphitic nature. The quartz has a granoblastic texture, while traces of the original clastic nature of the rock remain clear. Biotite occurs as small tabular flakes which are mainly isolated, but extremely iso-oriented, and only rarely present as little clusters. The homogenity of the rock is due to some zones of recrystallized quartz in larger elements. These zones are accompanied by the growth of poikiloblastic, tabular muscovite, not oriented parallel to the planes of schistosity.

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* This Index do not include the Appendices.

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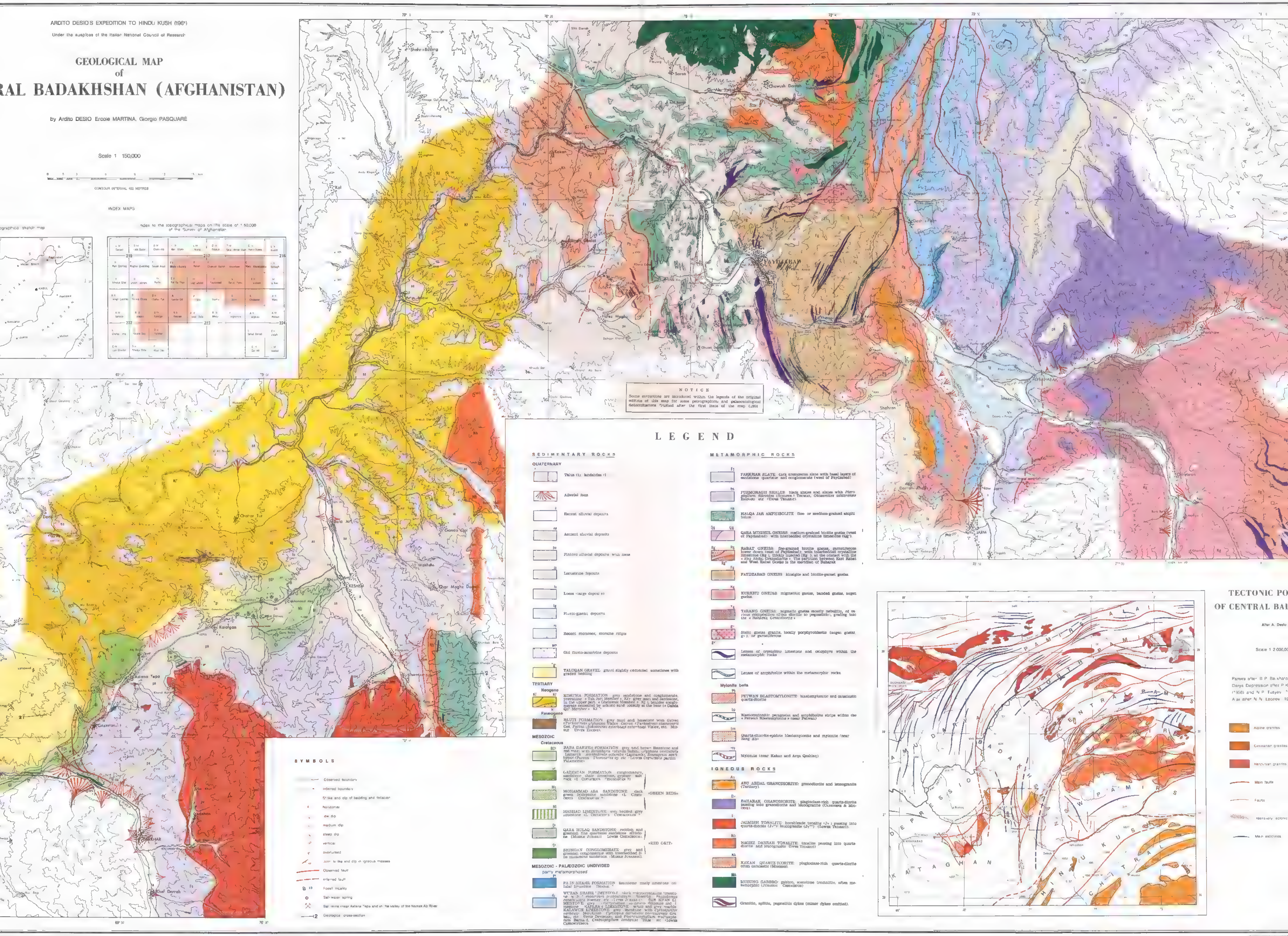

ARDITO DESIO'S EXPEDITION TO HINDU KUSH (1961)
Under the auspices of the Italian National Council of Research
GEOLOGICAL MAP
of
RAL BADAKHSHAN (AFGHANISTAN)
by Ardito DESIO Ercole MARTINA Giorgio PASQUARE
Scale 1 : 150,000
CONTOUR INTERVAL 100 METRES
INDEX MAPS
NOTICE
Some corrections are introduced within the legends of the original edition of this map for some petrographical and palaeontological determinations finished after the first issue of the map (1964
LEGEND
SEDIMENTARY ROCKS
QUATERNARY
Talus (t), landslides (l)
Alluvial fans
Recent alluvial deposits
Ancient alluvial deposits
Plateau alluvial deposits with loess
Lacustrine deposits
Loess (large deposits)
Fluvio-glacial deposits
Recent moraines; moraine ridges
Old fluvio-lacustrine deposits
TALUQAN GRAVEL: gravel slightly cemented, sometimes with graded bedding
TERTIARY
Neogene
KOKCHA FORMATION
Palæogene
BLUTI FORMATION
MESOZOIC
Cretaceous
BABA DARWES FORMATION
GAZESTAN FORMATION
MOHAMMAD ABA SANDSTONE
«GREEN BEDS»
MASHAD LIMESTONE
QARA BULAQ SANDSTONE
«RED GRIT»
SHINGAN CONGLOMERATE
MESOZOIC - PALÆOZOIC UNDIVIDED
partly metamorphosed
PA IN SHAHR FORMATION
WURAN SHAHR LIMESTONE
METAMORPHIC ROCKS
FARKHAR SLATE: dark arenaceous slate with basal layers of sandstone, quartzite and conglomerate (west of Faydzabad)
FURMORAGH SHALES
HALQA JAR AMPHIBOLITE: fine- or medium-grained amphibolite
QARA MUGHUL GNEISS
RABAT GNEISS
FAYDZABAD GNEISS: kinzigite and biotite-garnet gneiss.
KURKHU GNEISS: migmatitic gneiss, banded gneiss, augen gneiss.
TARANG GNEISS
Sialic gneiss granite, locally porphyroblastic (augen gneiss, gr), or garnetiferous
Lenses of crystalline limestone and calophyre within the metamorphic rocks
Lenses of amphibolite within the metamorphic rocks.
Mylonite belts
PETWAN BLASTOMYLONITE: blastomylonitic and cataclastic quartz-diorite
Quartz-chlorite-epidote blastomylonite and mylonite (near Sang Ab)
Mylonite (near Kakan and Arqa Qeshlaq)
IGNEOUS ROCKS
ABU ABDAL GRANODIORITE: granodiorite and leucogranite (Tertiary).
BAHARAK GRANODIORITE
JALMISH TONALITE
NAGHZ DARRAH TONALITE
KAKAN QUARTZ DIORITE
MUZUNG GABBRO
Granitic, aplitic, pegmatitic dykes (minor dykes omitted).
SYMBOLS
Observed boundary
Inferred boundary
Observed fault
Inferred fault
Fossil locality
Salt-water spring
Geological cross-section
TECTONIC PO
OF CENTRAL BA
PAMIRS
HINDU KUSH
KATAGHAN
ERSITY OF MILAN (ITALY) September 1964

BLE 2 - Summary of the Stratigraphy of Central Badakhshan.

AGE	ROCK UNITS AND SYMBOLS	THICKNESS	LITHOLOGY	PALAEONTOLOGY	STRATIGRAPHIC RELATIONSHIP	DEPOSITIONAL ENVIRONMENT	PHYSIOGRAPHIC EXPRESSION	TOPOGRAPHIC DISTRIBUTION	REMARKS
LEISTOCENE	Taluqan gravels Tgr	up to 300 m	gravel, sometimes slightly cemented, sometimes with graded bedding	—	unconformable on units of different ages	continental: terrestrial	gently sloping plains	large outcrops in the region between Kalafghan and the course of the Taluqan river	present only in th region south-west o Faydzabad
	Ghelawuk member Kf'	up to 1120 m	marl, sand, sandstone and conglomerate	rare Ostracods	conformable on (and interdigitates with) Tah Jari member	continental: terrestrial and lacustrine	undulating hills crossed by ravines	large outcrops along the Kokcha valley, downstream from Artin Jelaw	present only in th region south-west o Faydzabad
EOGENE	Kokcha Form. Tah Jari member Kf	up to 500 m	conglomerate, sandstone, sand	—	strongly unconformable on an intensely eroded surface cut across pre-Triassic to Eocene rocks; interdigitates with Ganda Qol member	continental	undulating hills crossed by ravines	large outcrops in the Kokcha valley, (downstream from Qara Kamar), and in the Hazara, Teshkan, Mashad and Shor valleys	present only in th region south-west o Faydzabad
	Ganda Qol member Kf"	up to 300 m	boulder conglomerate cemented by arcosic sand	—	strongly unconformable on pre-Triassic rocks; interdigitates with Tah Jari member	continental	undulating hills crossed by ravines	only in the Hazara, Teshkan, Wakhshi and Mashad valleys	present only in th region south-west o Faydzabad
IDDLE — UPPER OCENE	Bluti formation Bf	less than 50 m	marl and well-bedded limestone	*Ostrea* (*Turkostrea*) *afghanica* VIALOV, *Ostrea* (*Turkostrea*) *cizancourti* COX, *Fatina* (*Fatina*) *boehmi boehmi* (VIALOV)	(not visible)	marine: pelagic	poorly resistant; weakly inclined slopes and isolated ridge	only north of Kalafghan	present only in th region south-west o Faydzabad
AASTRICHTIAN — LBIAN ALAEOCENE (?) — OWER CRETACEOUS	Baba Darwes Formation BDf	about 400 m	well-bedded limestone, coquina and quartziferous limestone, reddish marl	*Fatina* (*Sokolovia*) *esterhazyi esterhazyi* (PAVAY, p. VIALOV), *Exogyra overwegi* VON BUCH, *Rectithyris subdepressa* (STOLICZKA), *Amphidonte decussata* (GOLDFUSS), *Ceratostreon spinosum* (MATHERON), *Trochactoeon matensis* (FITTIPALDI), *Thomasites* sp. ind., *Icthyosarcolites triangularis* DESMAREST, *Trigonarca diceras* (SEGUENZA), *Haustator multiplicatus* PCELINCEV, *Sauvagesia sanfilippoi* PARONA *Orbitocyclina minima* (DOUVILLÉ), *Orbitoides media* (D'ARCHIAC) *Siderolites calcitrapoides* LAMK., *Cuneolinae*, *Dicyclinae*, *Haplophragmoides* cf. *greigi* (HENSON), *Hedbergellae*	unconformable on Gazestan Formation and Mohammad Aba Sandstone.	sublittoral and or littoral marine; pelagic at the base	resistant or moderatley resistant: rugged topography with steep slopes	between the Mashad valley and the Taluqan river	present only in th region south-west o Faydzabad
ENOMANIAN (?) — OWER CRETACEOUS	Gazestan Formation Gf	up to 300 m	sandstone, marl, gypsum and limestone	probable articles of *Saccocoma*, rare *Miliolidae*	conformable on Qara Bulaq Sandstone; interdigitates with Mohammad Aba Sandstone; unconformably overlain by Baba Darwes Formation	shallow marine to lagoonal	poorly resistant; weakly inclined slopes and isolated hills	continuous horizon from Astana Tepa to the course of the Taluqan river	present only in th region south-west o Faydzabad
ENOMANIAN (?) — OWER CRETACEOUS	Mohammad Aba Sandstone Ms	up to 170 m	quartzose and quartzose-feldspathic sandstone	—	conformable on Mashad Limestone and Qara Bulaq Sandstone; interdigitates with Gazestan Formation; overlair by unconformable Baba Darwes Formation	epicontinental	poorly resistant; gentle slopes and hills	large outcrop between Kishem and Kalafghan	present only in th region south-west o Faydzabad
ENOMANIAN (?) — OWER CRETACEOUS	Mashad Limestone Ml	up to 80 m	well-bedded limestone	—	conformable on Qara Bulaq Sandstone; laterally granding to the Gazestan Formation; overlain by conformable Mohammad Aba Sandstone	epicontinental	resistant; abrupt cliffs	continuous horizon from Kishem to Qara Bulaq	present only in th region south-west o Faydzabad
OWER CRETACEOUS MIDDLE JURASSIC	Qara Bulaq Sandstone Qf	less than 200 m	conglomerate, granular conglomeratic, coarse sandstone, quartzose sandstone and arenaceous shale	rare plant remains	conformable on Shingan Conglomerate, and laterally grading to it; conformably overlain by Mashad Limestone and Gazestan Formation	continental	moderately resistant; gentle slopes and isolated hills	between the Mashad and Farkhar valleys	present only in th region south-west o Faydzabad
ROBABLY (UPPER) URASSIC	Pa-in-Shahr Formation Ps	?	crystalline limestone, with gypsum nests, marly, limonitic and dolomitic limestone, cellular dolomite, sandstone, conglomerate and breccia	—	probably unconformable on Kalawch Limestone; overlain by conformable Furmoragh shales	lagoonal	resistant or moderately resistant, rugged topography with steep slopes and small scarps	only east of Faydzabad: small belts near Pa-in-Shahr and in Syah Jar valley; small outcrops near Furmoragh and in Shiwa valley	present only in th region east of Fay zabad
PPER JURASSIC	Wuran Shar Limestone (djl)	?	microcrystalline limestone, oolitic limestone, dolomite	*Ctenostrem proboscideum* SOWERBY, *Pholadomya canaliculata* ROEMER	conformable on Furmoragh shales; eroded at the top.	marine: neritic	resistant; steep slopes, prominent ridges and abrupt walls	only east of Faydzabad: narrow elongated belt from Koh-i-Sur Khan to Syah Jar valley	present only in th region east of Fay zabad
IDDLE JURASSIC	Shingan Conglomerate Sf	up to 100 m	conglomerate and quartzose sandstone	rare plant remains	unconformable on pre-Triassic slates and igneous bodies	deltaic	resistant; steep slopes	small outcrops near Astana Tepa, Gazestan, and Shingan	present only in th region south-west Faydzabad
PPER TRIASSIC	Furmoragh shales bs (fossiliferous beds)	some hundred meters	shale, quartzose sandstone; quartzose feldspathic sandstone and conglomerate at the base	*Pterophyllum filicoides* (SCHLOTH.), THOMAS, *Pterophyllum kalawchiense* BARNARD, *Otozamites ashtarensis* BARNARD, *Taeniopteris pseudobrevis* BARNARD	conformable on Pa-in-shahr Formation; overlain by conformable Wurn Shahr Limestone	continental	moderately resistant; weakly inclined slopes	only east of Faydzabad: large ouctrops in the region between Wular, Jurm, Baharak and Shiwa valley	present only in th region east of Fay zabad
OWER CARBONIFE-OUS — UPPER DE-ONIAN	Kalawch Limestone (djl)	?	criptocrystalline limestone with calcite veins	*Fasciculophyllum multiseptatum* VON SCHOUPPÉ, *Caninophyllum tomiense* (TOMALCHEV), *Zaphrentites* sp. ind., *Cyrtospirifer verneuili* (MURCHISON), *Cyrtiopsis davidsoni barrauxensis* GRABAU	probably unconformable on Kaferan marbles and Sur Khan dolomite; probably overlain by unconformable Pa-in-Shahr Formation	marine	resistant; steep slopes, prominent ridges and abrupt walls	only in the region east of Faydzabad: narrow elongated belt from Koh-i-Sur Khan to Wuran Shahr pass	present only in th region east of Fay zabad
RE-TRIASSIC	Farkhar Slate Fs	about 2000 m	dark slate with crystalline limestone; quartzose sandstone and quartzose conglomerate (epimetamorphic)	—	unconformable on the plutonic bodies; overlain by unconformable Shingan Conglomerate and Qara Bulaq Sandstone	continental; shallow marine (epimetamorphic)	moderatly resistant weakly inclined slopes	only, in the region west of Faydzabad: large outcrops in the Farkhar, Mashad and upper Mazara valleys, and in the Kokcha valley near Qara Kamar	present only in th region east of Fay zabad

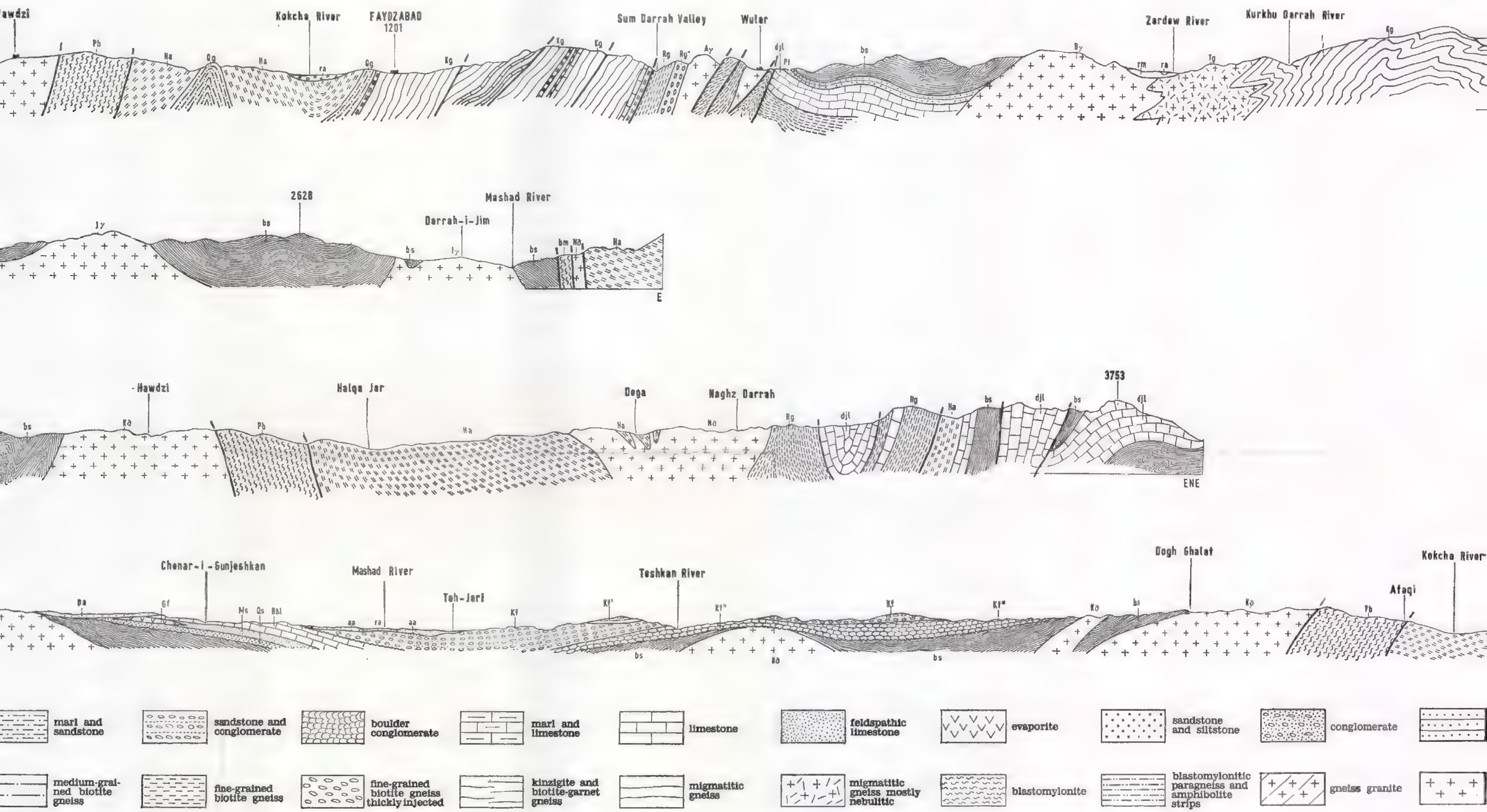


Fig. 42 a - Tectonic sections through Central Badakhshan.
(Desio, Martina & Pasquaré).

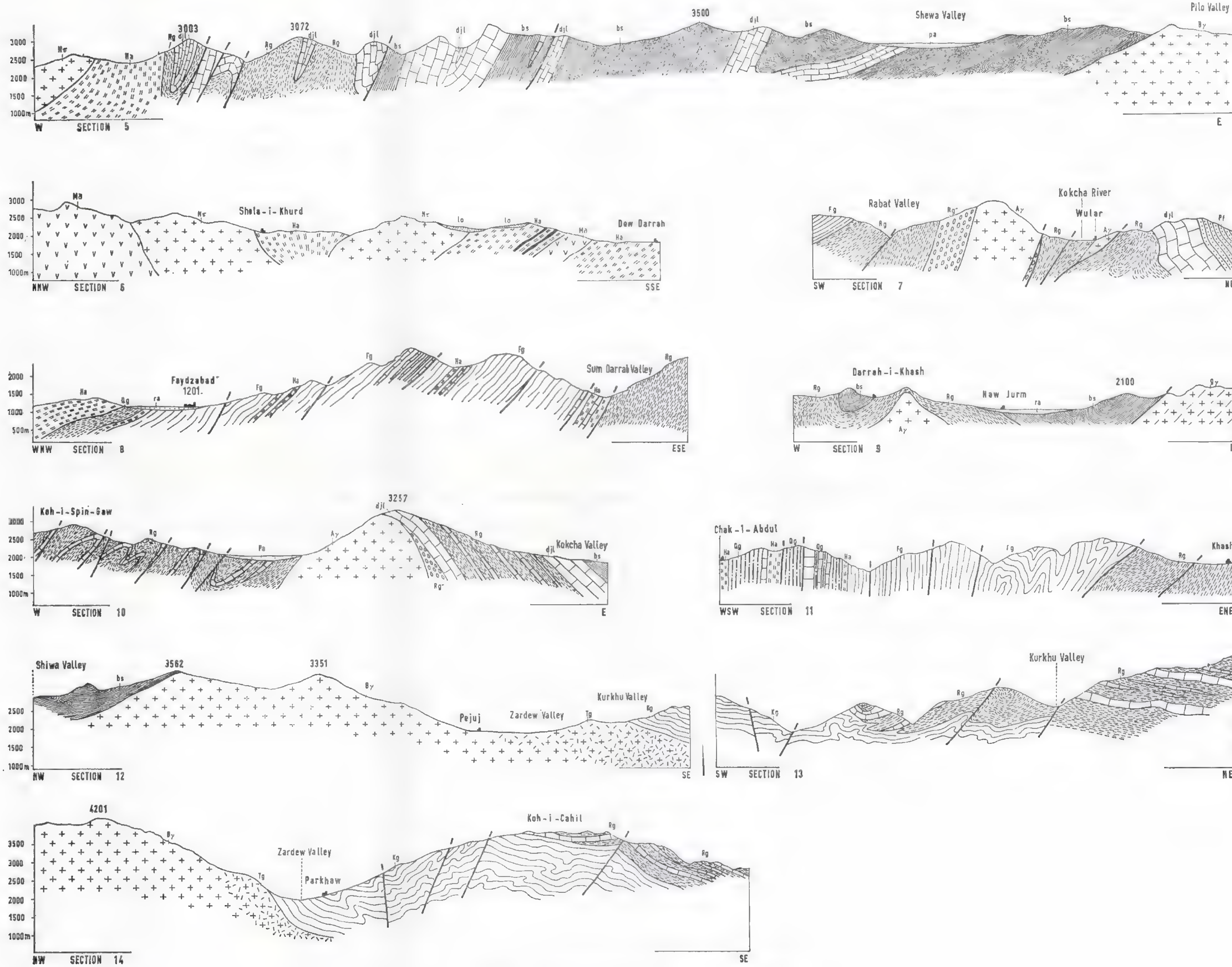
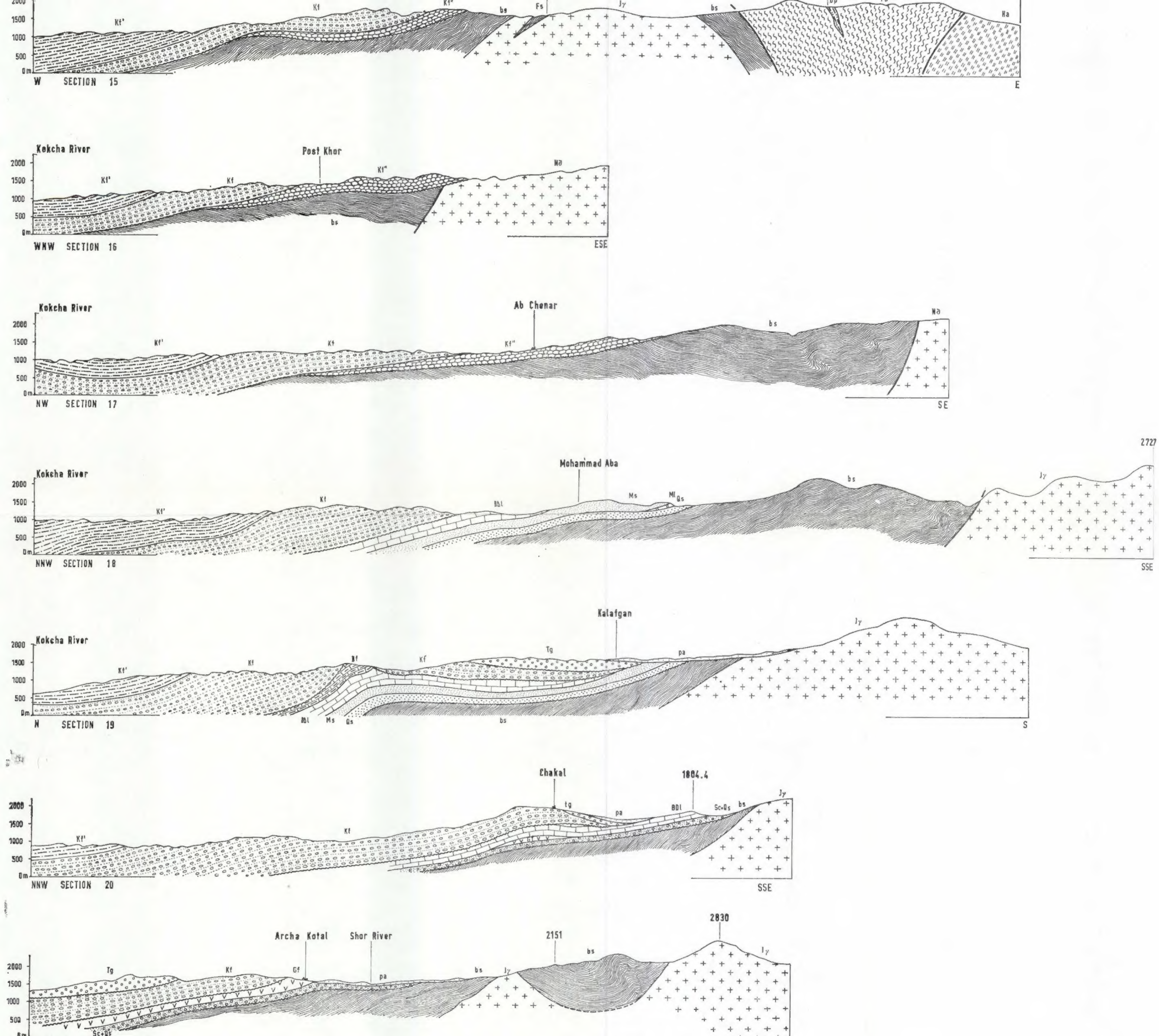


Fig. 42 b - Tectonic sections through Central Badakhshan.
(Desio, Martina & Pasquaré).



W SECTION 15
E
Kokcha River
Post Khor
WNW SECTION 16
ESE
Kokcha River
Ab Chenar
NW SECTION 17
SE
Kokcha River
Mohammad Aba
2727
NNW SECTION 18
SSE
Kokcha River
Kalafgan
N SECTION 19
S
Chakal
1804.4
NNW SECTION 20
SSE
Archa Kotal
Shor River
2151
2830

ERRATA CORRIGE

Page	*Line*	*Errata*	*Corrige*
33	10	*Pholadomia*	*Pholadomya*
21	24	Maskad	Mashad
27	5	MURCHINSON	MURCHISON
33	33	Sar-i-Houwidz	Sar-i-Hawdz
49	21	Kho-i-Shagarak	Koh-i-Shagarak
49	31	Shingam	Shingan
50	14	Darrah-i-Shab Baba	Darrah-i-Shah Baba
100	29	reddis	reddish
120	27	Cungha-i-Ulya	Cugha-i-Ulya
121	caption of Fig. 23	Ambar Formation	Ambar Koh Formation
123	20/21	*kaulanum*	*kanlanum*
124	30	*khadaguensis*	*khaudaguensis*
127	5	Lutetian-Priabonian	Lutetian (Priabonian)
131	12	*kauleanum*	*kanleanum*
131	12	*Otsrea*	*Ostrea*
131	12	*Kakanostrea kakanense*	*Kokanostrea kokanense*
132	4	*cauleanum*	*kanleanum*
134	10	*kauleanum*	*kanleanum*
150	6	Summsar	Sumssar
167	4	Abtal granite	Abdal granodiorite
193	20	Moshad	Mashad
197	19	Tertialri	Tertiary
212	19	pluton	plutons
216	5	Sela-i-Kadan	Sela-i-Kalan
224	7 (of the caption)	Aphibolite	Amphibolite
224	7	Calphyre	Calcphyre
287	2 (of the caption)	granodio	granodiorite
287	16	Deh Gal	Deh Gol
298	caption of Fig. 39	Babatangi Granite	Babatangi Granodiorite
382	fig. 51	1. loes	1. loess
416	last line	Plate Tectonic Elsevier	*Plate Tectonics*, Elsevier

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